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Lee et al.

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(54) **APPARATUS AND METHOD FOR ELIMINATING NOISE, SOUND RECOGNITION APPARATUS USING THE APPARATUS AND VEHICLE EQUIPPED WITH THE SOUND RECOGNITION APPARATUS**

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(73) Assignee: **Hyundai Motor Company**, Seoul (KR)

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G10L 21/0232 (2013.01)

(52) **U.S. Cl.**
CPC ***G10L 21/0232*** (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

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(57) **ABSTRACT**

An apparatus for eliminating noise includes: a gain acquisition unit that determines a gain and a correction value of the gain using a signal to noise ratio (SNR) of an input signal; and a gain application unit that acquires an output signal corresponding to the input signal using the determined gain and the determined correction value, wherein the output signal includes an input signal of which noise is eliminated and an input signal of which noise is not eliminated, and a proportion of the input signal of which noise is eliminated and a proportion of the input signal of which noise is not eliminated are determined according to the determined correction value.

16 Claims, 14 Drawing Sheets

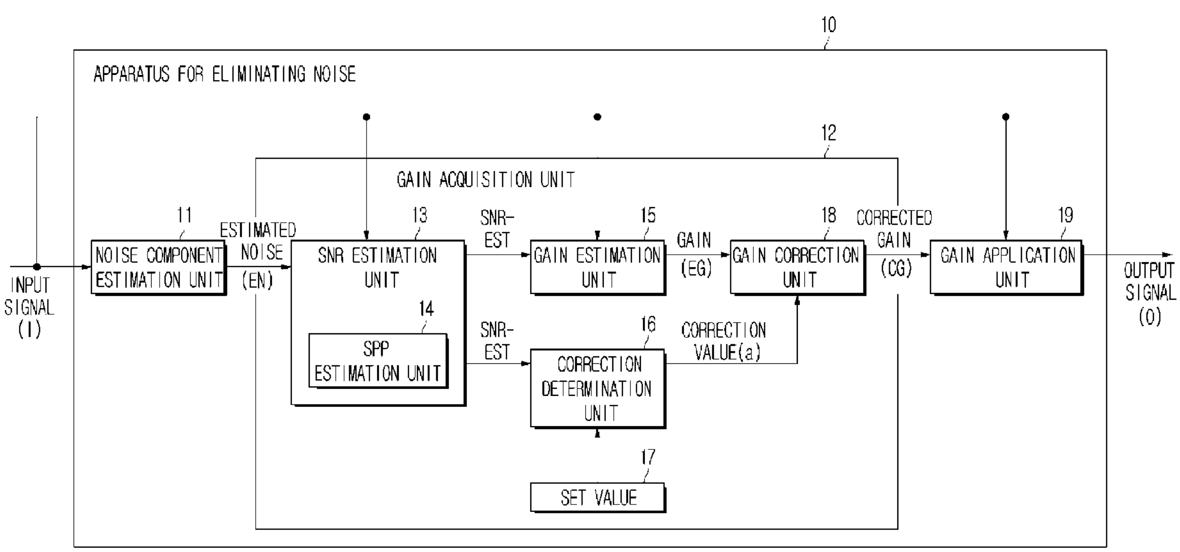
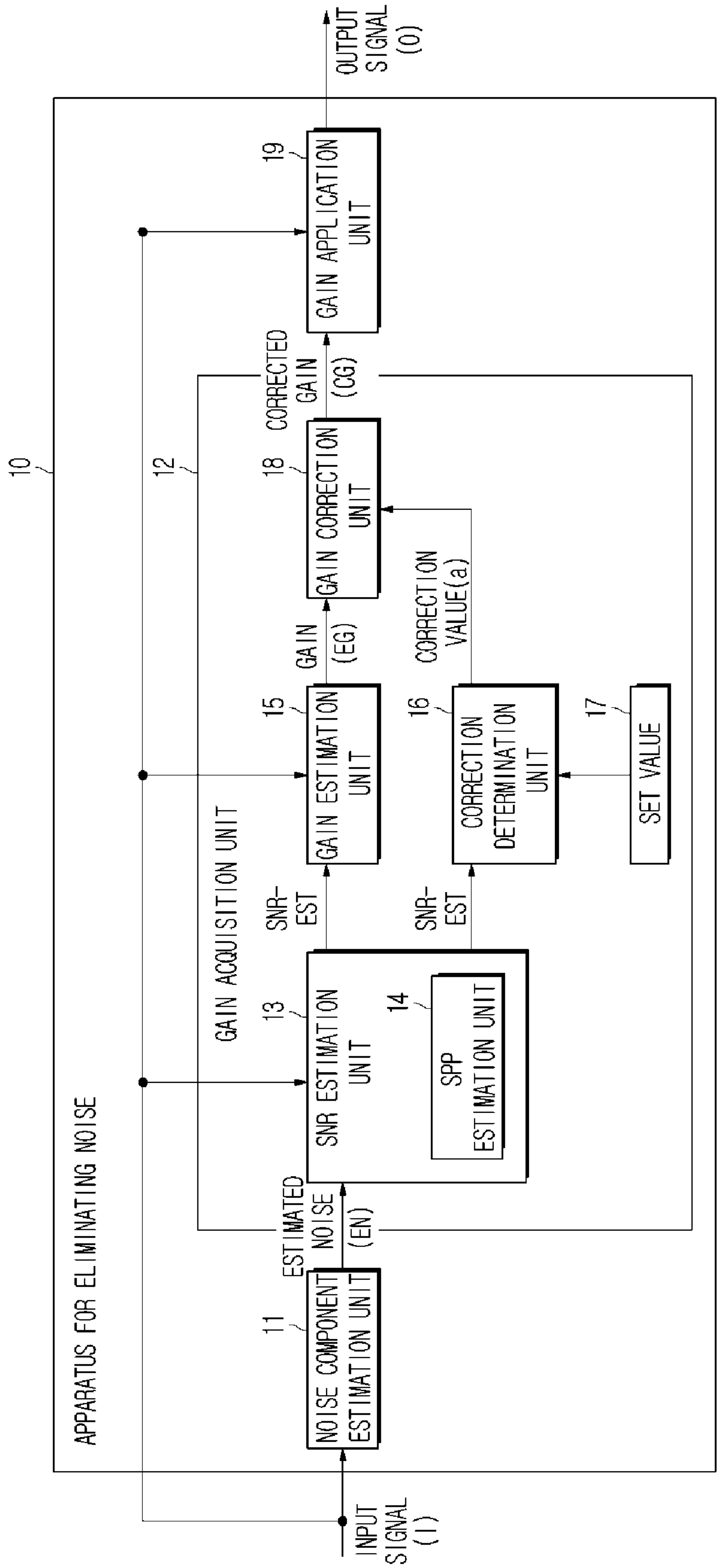


FIG. 1



APPARATUS FOR ELIMINATING NOISE
10
GAIN ACQUISITION UNIT
12
INPUT SIGNAL (I)
11
NOISE COMPONENT ESTIMATION UNIT
ESTIMATED NOISE (EN)
13
SNR ESTIMATION UNIT
14
SPP ESTIMATION UNIT
SNR-EST
SNR-EST
15
GAIN ESTIMATION UNIT
16
CORRECTION DETERMINATION UNIT
17
SET VALUE
GAIN (EG)
CORRECTION VALUE(a)
18
GAIN CORRECTION UNIT
CORRECTED GAIN (CG)
19
GAIN APPLICATION UNIT
OUTPUT SIGNAL (O)

FIG. 2

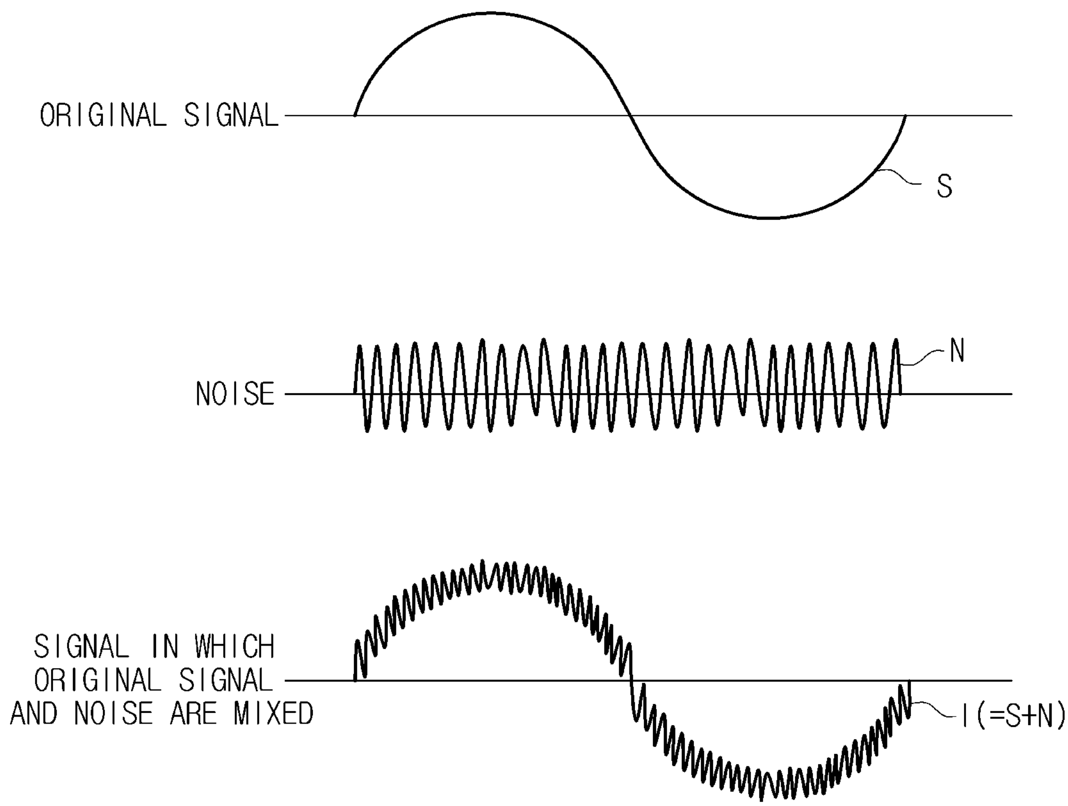

ORIGINAL SIGNAL
S
NOISE
N
SIGNAL IN WHICH ORIGINAL SIGNAL AND NOISE ARE MIXED
I(=S+N)

FIG. 3

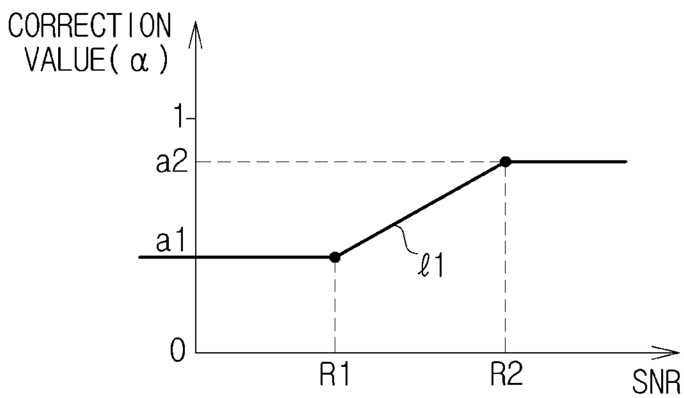


FIG. 4

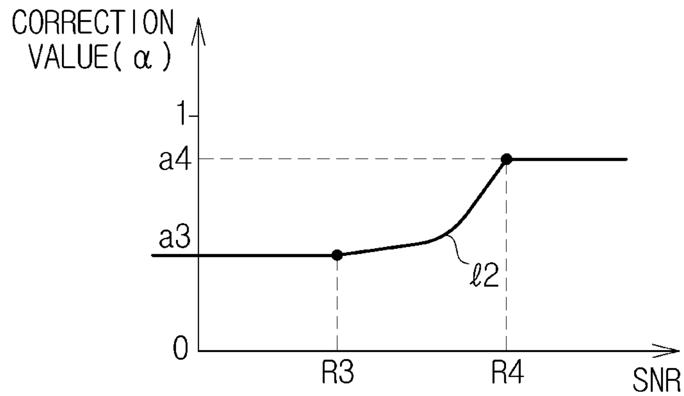


FIG. 5

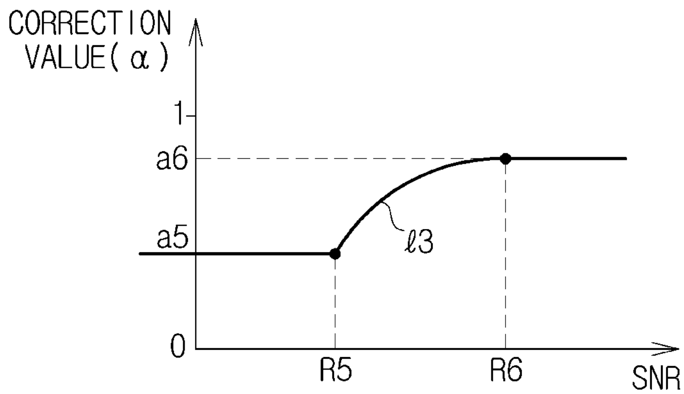


FIG. 6

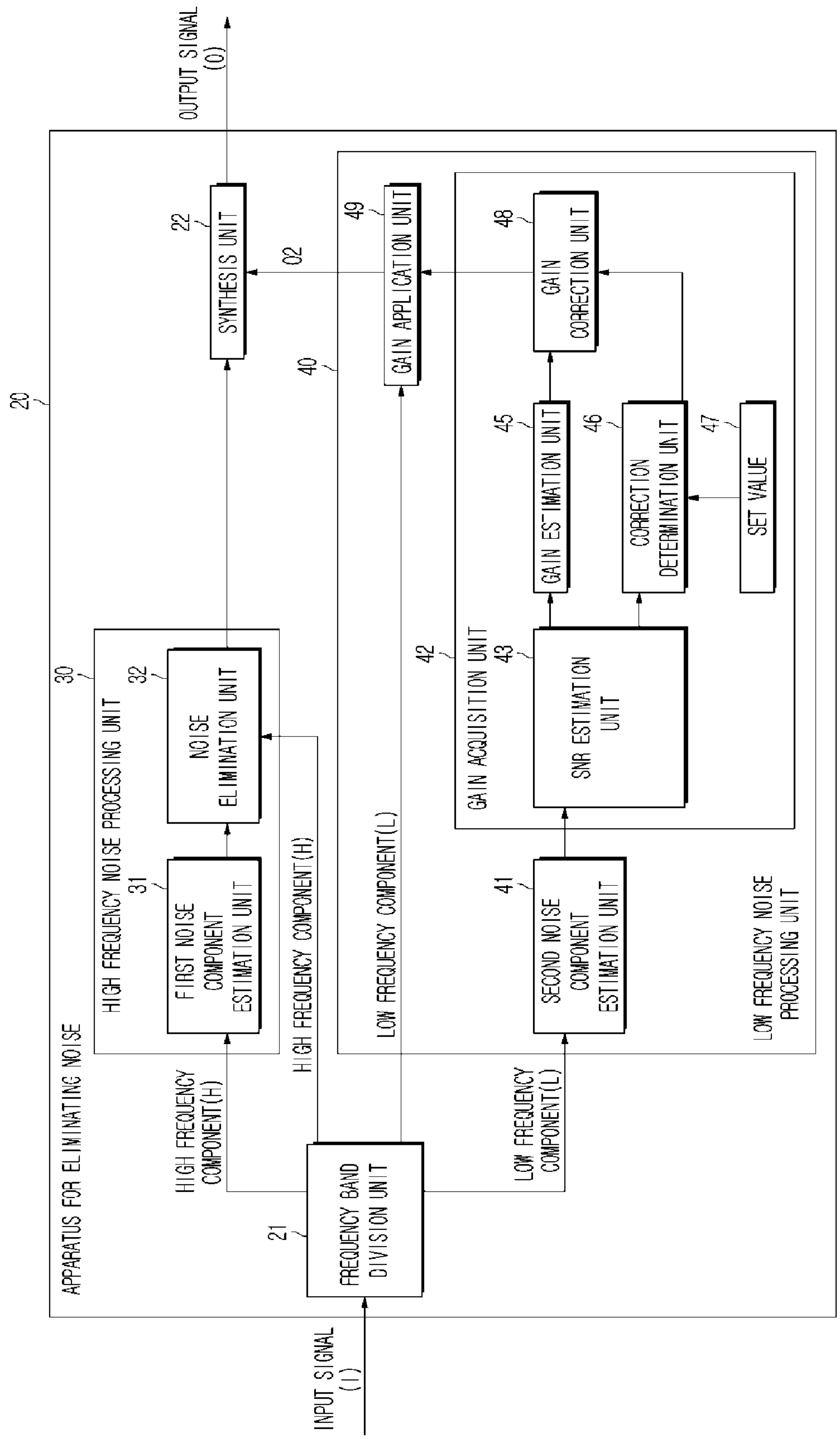

OUTPUT SIGNAL (O)
20
APPARATUS FOR ELIMINATING NOISE
21
FREQUENCY BAND DIVISION UNIT
INPUT SIGNAL (I)
HIGH FREQUENCY COMPONENT(H)
LOW FREQUENCY COMPONENT(L)
30
HIGH FREQUENCY NOISE PROCESSING UNIT
31
FIRST NOISE COMPONENT ESTIMATION UNIT
32
NOISE ELIMINATION UNIT
22
SYNTHESIS UNIT
O2
40
LOW FREQUENCY NOISE PROCESSING UNIT
41
SECOND NOISE COMPONENT ESTIMATION UNIT
42
GAIN ACQUISITION UNIT
43
SNR ESTIMATION UNIT
45
GAIN ESTIMATION UNIT
46
CORRECTION DETERMINATION UNIT
47
SET VALUE
48
GAIN CORRECTION UNIT
49
GAIN APPLICATION UNIT

FIG. 7

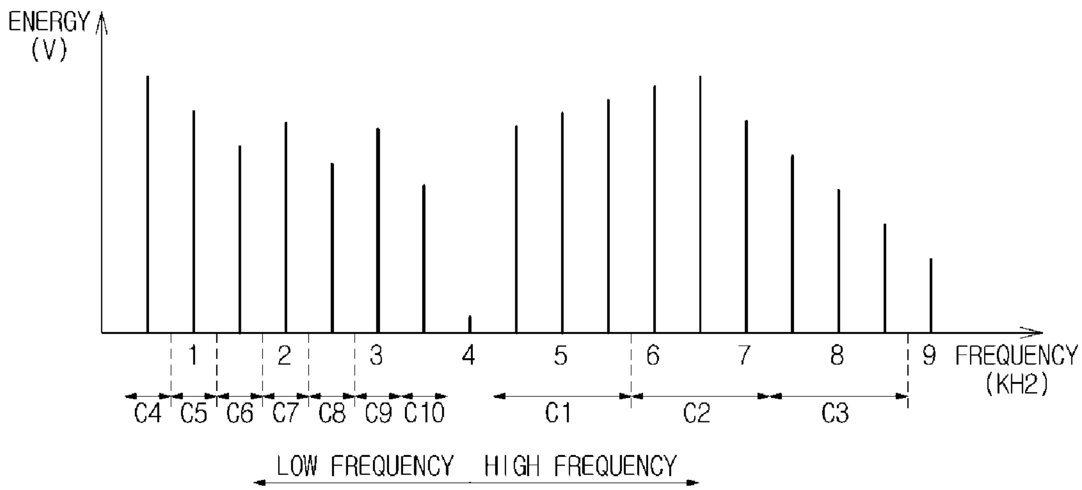

ENERGY (V)
1
2
3
4
5
6
7
8
9
FREQUENCY (KH2)
C4
C5
C6
C7
C8
C9
C10
C1
C2
C3
LOW FREQUENCY
HIGH FREQUENCY

FIG. 8

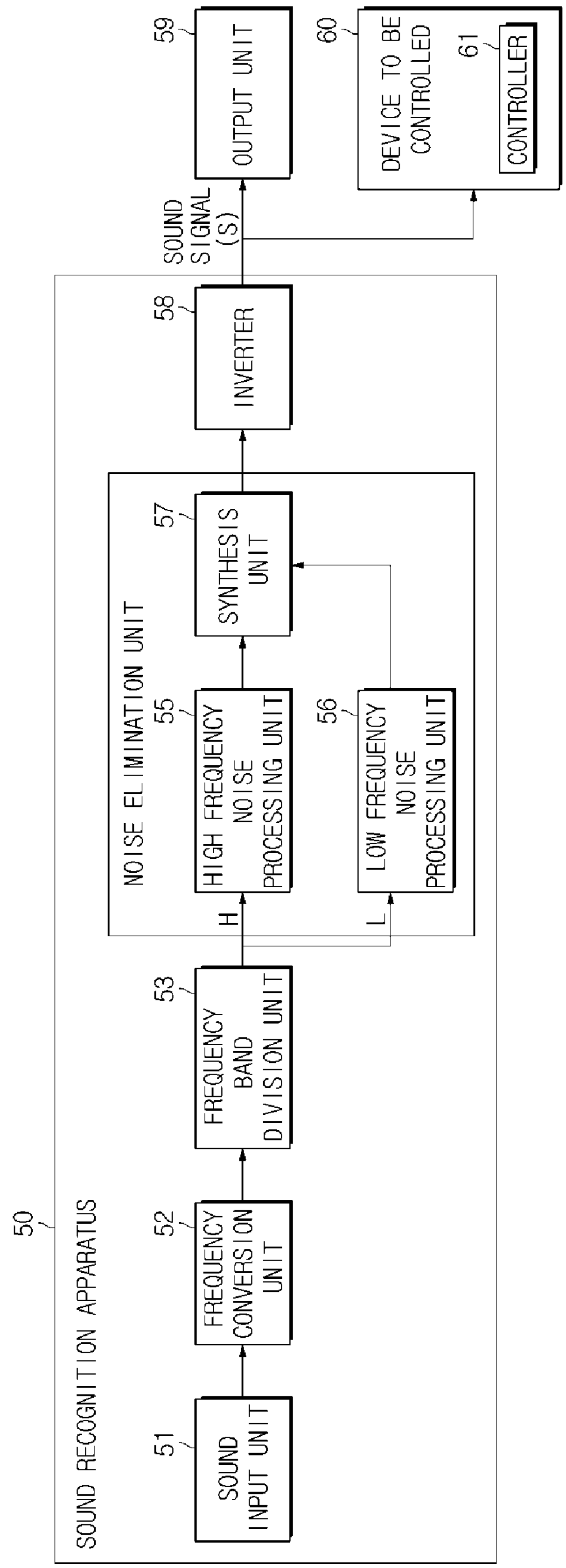

50
SOUND RECOGNITION APPARATUS
51
SOUND INPUT UNIT
52
FREQUENCY CONVERSION UNIT
53
FREQUENCY BAND DIVISION UNIT
H
L
NOISE ELIMINATION UNIT
55
HIGH FREQUENCY NOISE PROCESSING UNIT
56
LOW FREQUENCY NOISE PROCESSING UNIT
57
SYNTHESIS UNIT
58
INVERTER
SOUND SIGNAL (S)
59
OUTPUT UNIT
60
DEVICE TO BE CONTROLLED
61
CONTROLLER

FIG. 9

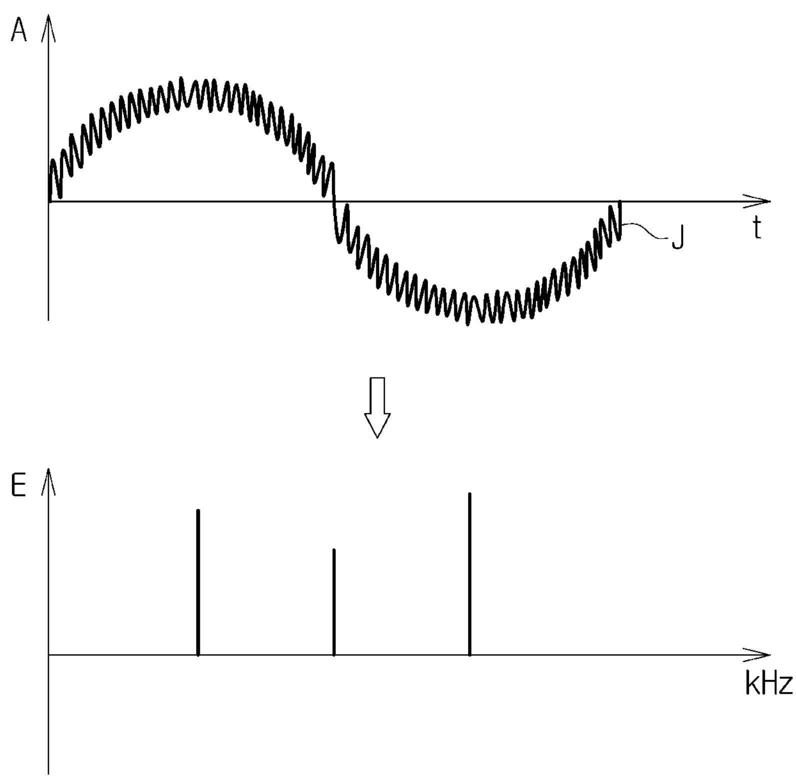


FIG. 10

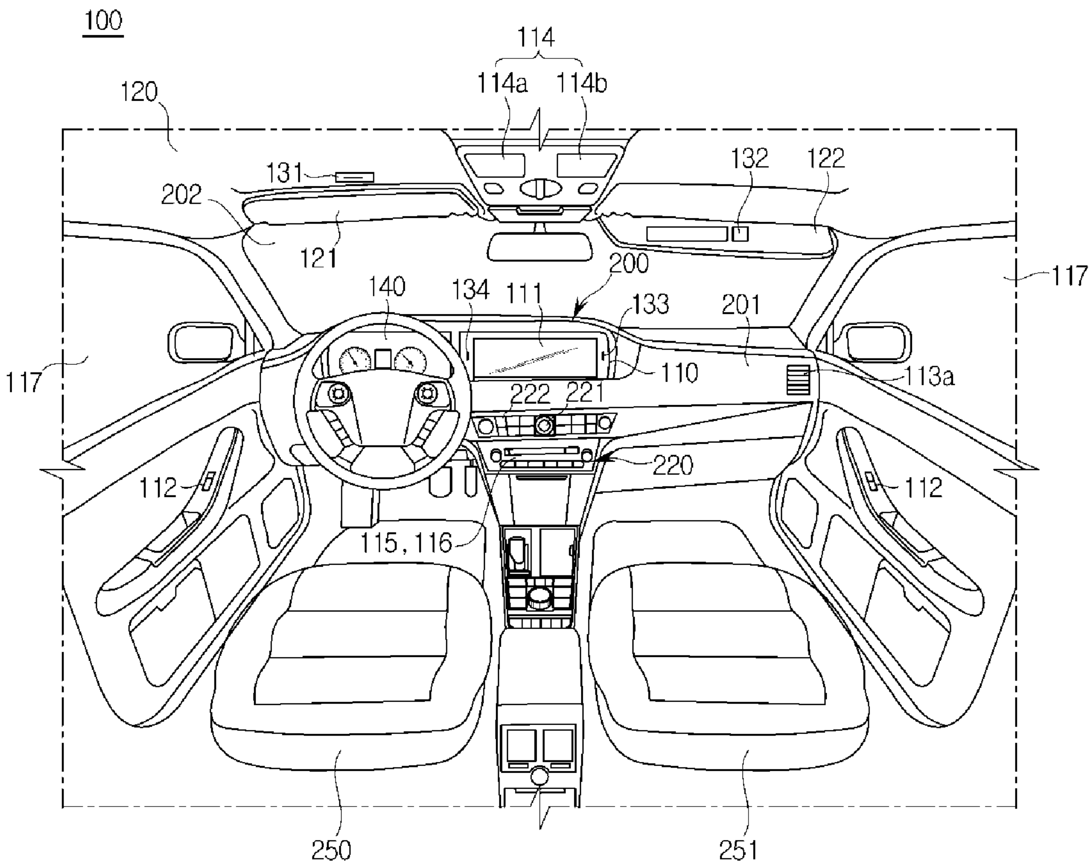

100
114
114a
114b
120
131
132
122
202
121
200
117
140
134
111
133
201
110
113a
222
221
112
220
115, 116
250
251

FIG. 11

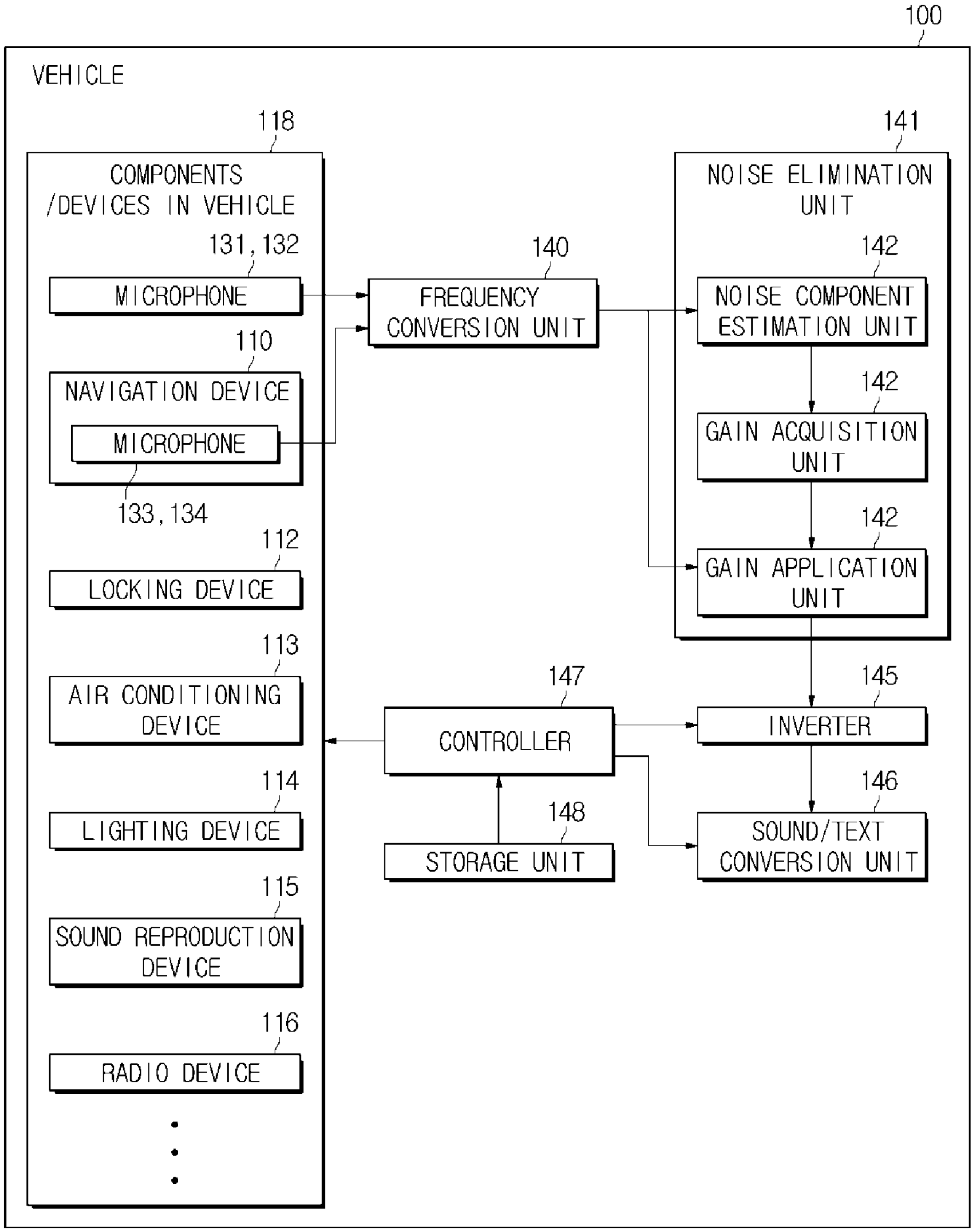

100
VEHICLE
118
COMPONENTS /DEVICES IN VEHICLE
131,132
MICROPHONE
110
NAVIGATION DEVICE
MICROPHONE
133,134
112
LOCKING DEVICE
113
AIR CONDITIONING DEVICE
114
LIGHTING DEVICE
115
SOUND REPRODUCTION DEVICE
116
RADIO DEVICE
140
FREQUENCY CONVERSION UNIT
141
NOISE ELIMINATION UNIT
142
NOISE COMPONENT ESTIMATION UNIT
142
GAIN ACQUISITION UNIT
142
GAIN APPLICATION UNIT
147
CONTROLLER
148
STORAGE UNIT
145
INVERTER
146
SOUND/TEXT CONVERSION UNIT

FIG. 12

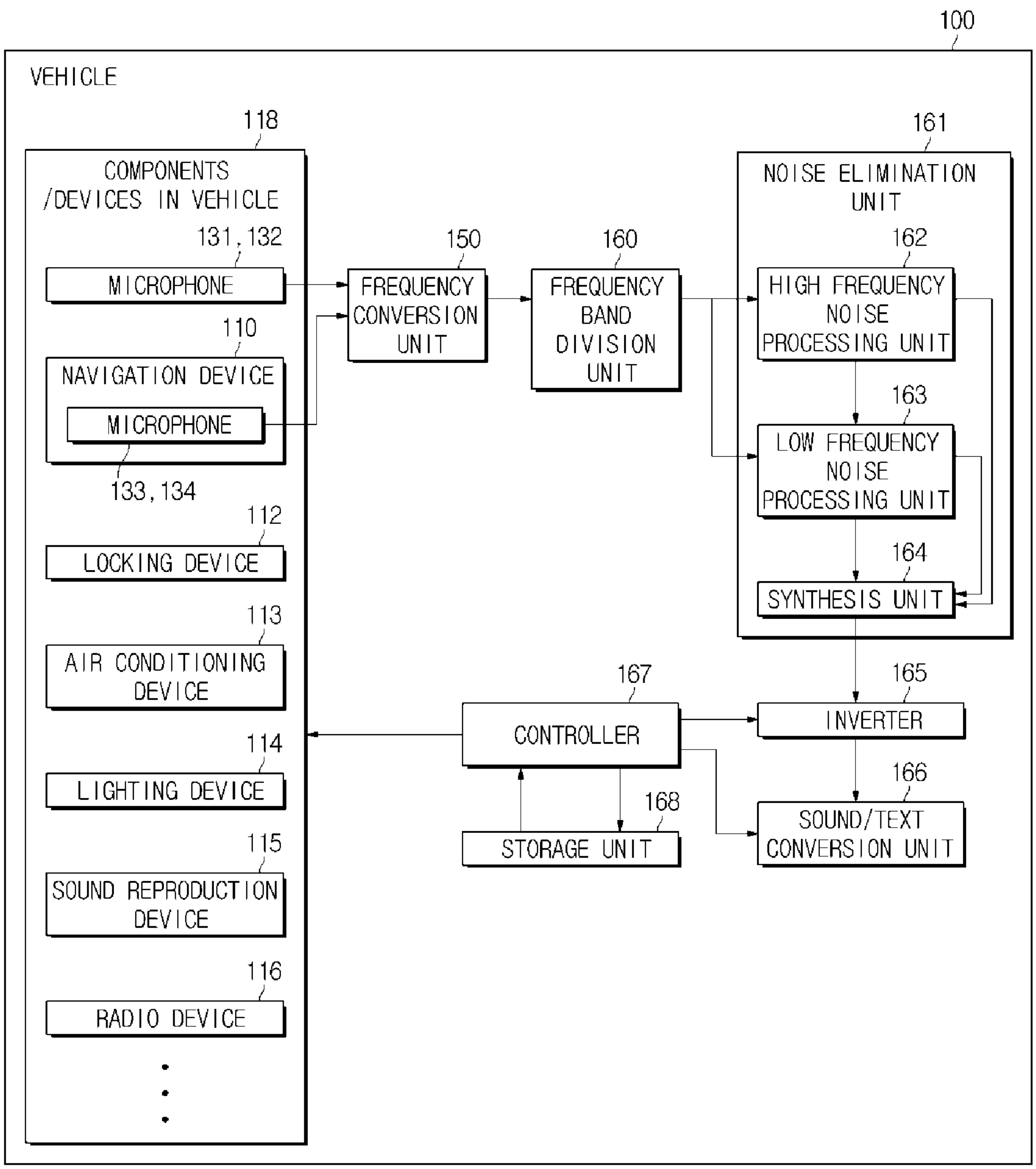

100
VEHICLE
118
COMPONENTS /DEVICES IN VEHICLE
131,132
MICROPHONE
110
NAVIGATION DEVICE
MICROPHONE
133,134
112
LOCKING DEVICE
113
AIR CONDITIONING DEVICE
114
LIGHTING DEVICE
115
SOUND REPRODUCTION DEVICE
116
RADIO DEVICE
150
FREQUENCY CONVERSION UNIT
160
FREQUENCY BAND DIVISION UNIT
161
NOISE ELIMINATION UNIT
162
HIGH FREQUENCY NOISE PROCESSING UNIT
163
LOW FREQUENCY NOISE PROCESSING UNIT
164
SYNTHESIS UNIT
167
CONTROLLER
165
INVERTER
168
STORAGE UNIT
166
SOUND/TEXT CONVERSION UNIT

FIG. 13

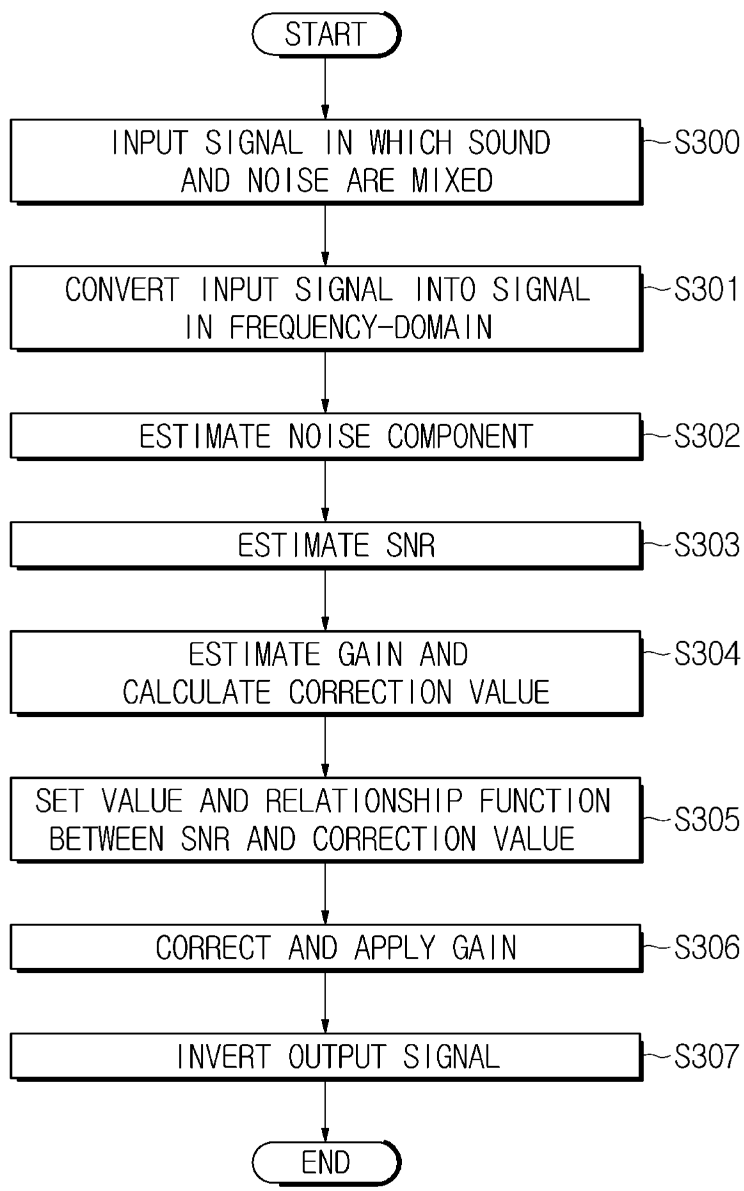
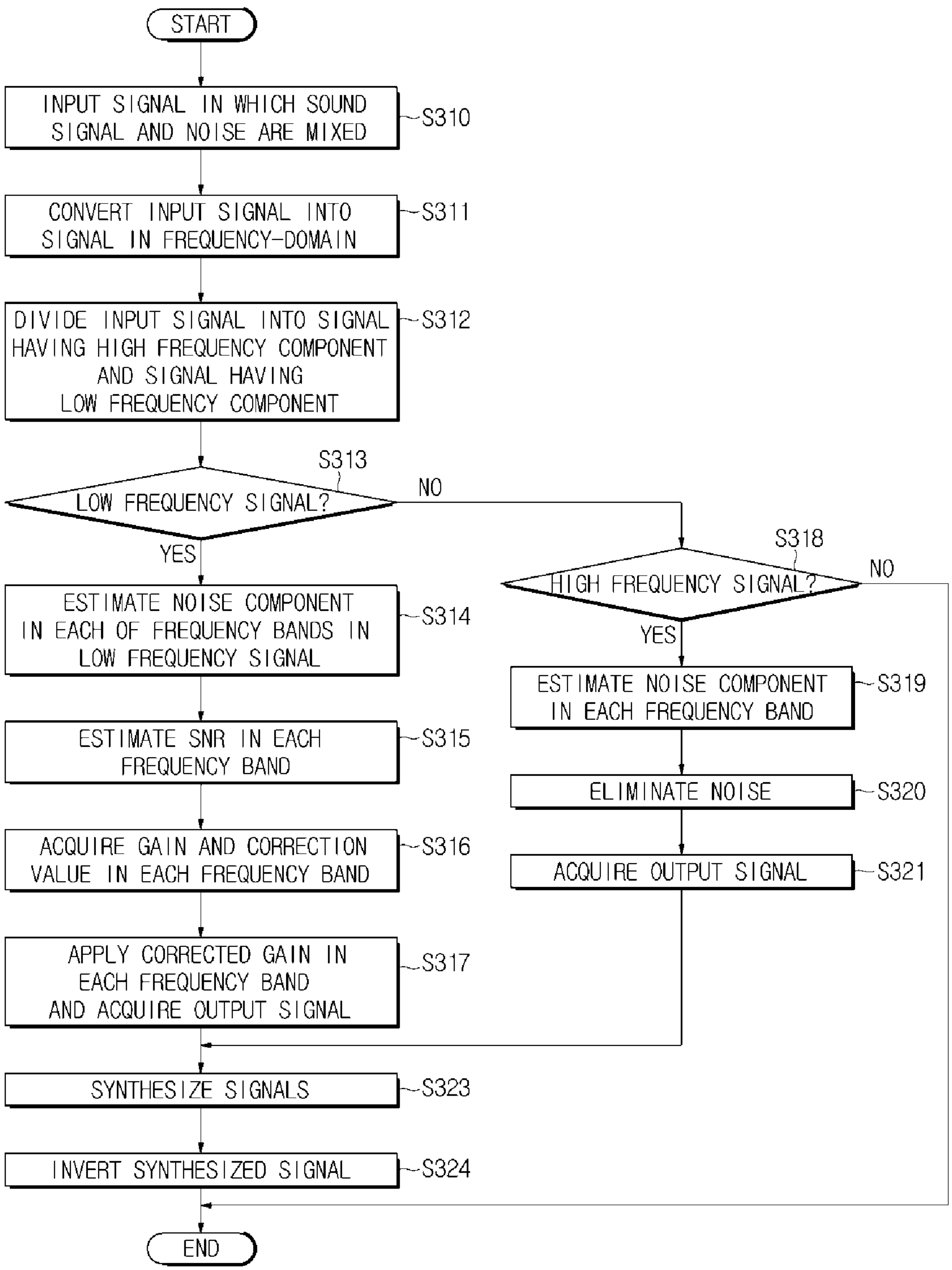

START
INPUT SIGNAL IN WHICH SOUND AND NOISE ARE MIXED
S300
CONVERT INPUT SIGNAL INTO SIGNAL IN FREQUENCY-DOMAIN
S301
ESTIMATE NOISE COMPONENT
S302
ESTIMATE SNR
S303
ESTIMATE GAIN AND CALCULATE CORRECTION VALUE
S304
SET VALUE AND RELATIONSHIP FUNCTION BETWEEN SNR AND CORRECTION VALUE
S305
CORRECT AND APPLY GAIN
S306
INVERT OUTPUT SIGNAL
S307
END

FIG. 14


START
INPUT SIGNAL IN WHICH SOUND SIGNAL AND NOISE ARE MIXED
S310
CONVERT INPUT SIGNAL INTO SIGNAL IN FREQUENCY-DOMAIN
S311
DIVIDE INPUT SIGNAL INTO SIGNAL HAVING HIGH FREQUENCY COMPONENT AND SIGNAL HAVING LOW FREQUENCY COMPONENT
S312
S313
LOW FREQUENCY SIGNAL?
NO
YES
S318
HIGH FREQUENCY SIGNAL?
NO
YES
ESTIMATE NOISE COMPONENT IN EACH OF FREQUENCY BANDS IN LOW FREQUENCY SIGNAL
S314
ESTIMATE NOISE COMPONENT IN EACH FREQUENCY BAND
S319
ESTIMATE SNR IN EACH FREQUENCY BAND
S315
ELIMINATE NOISE
S320
ACQUIRE GAIN AND CORRECTION VALUE IN EACH FREQUENCY BAND
S316
ACQUIRE OUTPUT SIGNAL
S321
APPLY CORRECTED GAIN IN EACH FREQUENCY BAND AND ACQUIRE OUTPUT SIGNAL
S317
SYNTHESIZE SIGNALS
S323
INVERT SYNTHESIZED SIGNAL
S324
END

APPARATUS AND METHOD FOR ELIMINATING NOISE, SOUND RECOGNITION APPARATUS USING THE APPARATUS AND VEHICLE EQUIPPED WITH THE SOUND RECOGNITION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of Korean Patent Application No. 10-2014-0120256, filed on Sep. 11, 2014 in the Korean Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND

1. Technical Field

Embodiments of the present disclosure relate to an apparatus and method for eliminating noise, a sound recognition apparatus using the apparatus and a vehicle equipped with the sound recognition apparatus.

2. Description of the Related Art

As is known in the art, a vehicle is a transportation means that can transport an object, such as a human being or cargo, to another position while travelling, e.g., on a road or railroad tracks. A vehicle can move mainly through rotation of one or more wheels installed at a body thereof. Examples of vehicles include three-wheeled and four-wheeled motor vehicles, two-wheeled motor vehicles, such as motorcycles, motorized bicycles, construction machines, bicycles, and trains, which travel on railroad tracks.

A sound recognition apparatus may be installed in a vehicle. The sound recognition apparatus is an apparatus that can recognize a sound generated by speech of a user, e.g., a driver or a passenger. When a sound of the vehicle is recognized by the sound recognition apparatus, a controller inside the vehicle transmits control signals corresponding to the recognized sound to components of the vehicle so that the components can operate according to the sound. When the sound recognition apparatus is used in this way, the user can control the components of the vehicle using sound, thus increasing convenience and safety for the user.

SUMMARY

Therefore, it is an aspect of the present disclosure to provide an apparatus for eliminating noise that is capable of improving a sound recognition rate even when there is much noise, a method of eliminating noise, a sound recognition apparatus using the apparatus and a vehicle equipped with the sound recognition apparatus. It is another aspect of the present disclosure to provide an apparatus for eliminating noise that is capable of improving performance of sound recognition with a relatively small amount of calculation, a method of eliminating noise, a sound recognition apparatus using the apparatus and a vehicle equipped with the sound recognition apparatus. Additional aspects of the present disclosure will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the disclosure.

In accordance with embodiments of the present disclosure, there is provided an apparatus for eliminating noise, the apparatus including: a gain acquisition unit that determines a gain and a correction value of the gain using a signal to noise ratio (SNR) of an input signal; and a gain application unit that acquires an output signal corresponding to the

input signal using the determined gain and the determined correction value, wherein the output signal may include an input signal of which noise is eliminated and an input signal of which noise is not eliminated, and a proportion of the input signal of which noise is eliminated and a proportion of the input signal of which noise is not eliminated may be determined according to the determined correction value.

The gain acquisition unit may determine the correction value of the gain based on the SNR.

The gain acquisition unit may determine the correction value of the gain based further on a set value associated with a relationship between the SNR of the input signal and the correction value, and may change the relationship between the SNR of the input signal and the correction value based on the set value, wherein the set value may indicate a performance of a sound recognition apparatus.

The correction value may be determined in such a way that the correction value increases as the SNR of the input signal increases, or that the correction value has a uniform value when the SNR of the input signal is less than a first value or is greater than a second value.

The correction value may be determined in such a way that the proportion of the input signal of which noise is eliminated increases when the SNR of the input signal increases, while the proportion of the input signal of which noise is not eliminated increases when the SNR of the input signal decreases.

The apparatus may further include a noise component estimation unit that estimates noise of the input signal using at least one of a minima controlled recursive averaging (MCRA) algorithm, an improved minima controlled recursive averaging (IMCRA) algorithm, and a minimum statistics algorithm.

The apparatus may further include a SNR estimation unit that estimates the SNR of the input signal using at least one of a minimum mean square error (MMSE), a root mean square (RMS) error, a cumulative minimum distance (CMD), and a speech presence probability (SPP).

Furthermore, in accordance with embodiments of the present disclosure, there is provided an apparatus for eliminating noise, including: a frequency band division unit that divides an input signal into a signal having a high frequency component and a signal having a low frequency component; a high frequency noise processing unit that eliminates noise of the signal having the high frequency component based on a low resolution analysis algorithm; a low frequency noise processing unit that eliminates noise of the signal having the low frequency component based on a high resolution analysis algorithm; and a synthesis unit that synthesizes a signal processed by the high frequency noise processing unit with a signal processed by the low frequency noise processing unit.

The low frequency noise processing unit may determine a gain and a correction value of the gain using an SNR of the input signal and may acquire an output signal by applying a corrected gain obtained by applying the determined correction value to the determined gain, wherein a proportion of the input signal of which noise is eliminated in the output signal and a proportion of the input signal of which noise is not eliminated in the output signal may be changed according to the determined correction value.

The high frequency noise processing unit may estimate noise from an initial signal of the input signal and may eliminate noise of the signal having the high frequency component using the estimated noise.

Furthermore, in accordance with embodiments of the present disclosure, there is provided a sound recognition apparatus including: an input unit that receives a sound signal in which an original signal and noise are mixed; a conversion unit that converts the sound signal into a signal in a frequency-domain; a gain acquisition unit that determines a gain and a correction value of the gain using an SNR of the sound signal and acquires a corrected gain obtained by applying the determined correction value to the determined gain; a gain application unit that acquires an output signal by applying the corrected gain to the sound signal, wherein a proportion of the input signal of which noise is eliminated in the output signal and a proportion of the input signal of which noise is not eliminated in the output signal are changed according to the determined correction value; and an inverter that inverts the output signal.

Furthermore, in accordance with embodiments of the present disclosure, there is provided a sound recognition apparatus including: an input unit that receives a sound signal in which an original signal and noise are mixed; a frequency band division unit that divides an input signal into a signal having a high frequency component and a signal having a low frequency component; a high frequency noise processing unit that eliminates noise of the signal having the high frequency component based on a low resolution analysis algorithm; a low frequency noise processing unit that eliminates noise of the signal having the low frequency component based on a high resolution analysis algorithm; and a synthesis unit that synthesizes a signal processed by the high frequency noise processing unit with a signal processed by the low frequency noise processing unit.

The high frequency noise processing unit may estimate noise from an initial signal of the input signal and may eliminate noise of the signal having the high frequency component using the estimated noise.

Furthermore, in accordance with embodiments of the present disclosure, there is provided a vehicle including: an input unit that receives a sound signal from a passenger of the vehicle in which sound instructions and noise are mixed together; a sound recognition unit that recognizes sound instructions by: i) converting the received sound signal into a signal in a frequency-domain, ii) determining a gain and a correction value of the gain using a an SNR of the signal in the frequency-domain, iii) acquiring an output signal by applying a corrected gain obtained by applying the determined correction value to the determined gain, and iv) inverting the output signal, wherein a proportion of the received sound signal of which noise is eliminated in the output signal and a proportion of the received sound signal of which noise is not eliminated in the output signal are changed based on the determined correction value; and a controller that generates a control signal based on the recognized sound instructions.

Furthermore, in accordance with embodiments of the present disclosure, there is provided a vehicle including: an input unit that receives a sound signal from a passenger of the vehicle in which sound instructions and noise are mixed together; a frequency band division unit that divides the received sound signal into a signal having a high frequency component and a signal having a low frequency component; a sound recognition unit that: i) eliminates noise of the signal having the high frequency component based on a low resolution analysis algorithm, ii) eliminates noise of the signal having the low frequency component based on a high resolution analysis algorithm, iii) synthesizes the signal having the high frequency component of which noise is eliminated with the signal having the low frequency component of which noise is eliminated, and iv) recognizes sound instructions based on the synthesized signal; and a controller that generates a control signal based on the recognized sound instructions.

Furthermore, in accordance with embodiments of the present disclosure, there is provided a method of eliminating noise, including: determining a gain and a correction value of the gain using an SNR of an input signal; acquiring a corrected gain obtained by applying the determined correction value to the determined gain; and acquiring an output signal by applying the corrected gain to the input signal, wherein a proportion of an input signal of which noise is eliminated in the output signal and a proportion of the input signal of which noise is not eliminated in the output signal are changed based on the determined correction value.

The determining of the correction value of the gain may include determining the correction value of the gain based on a relationship between the SNR of the input signal and the correction value.

The determining of the correction value of the gain may include determining the correction value of the gain based further on using a set value associated with a relationship between the SNR of the input signal and the correction value.

The correction value may be determined in such a way that the correction value increases as the SNR of the input signal increases, or the correction value has a uniform value when the SNR of the input signal is less than a first value or is greater than a second value.

The correction value may be determined in such a way that the proportion of the input signal of which noise is eliminated increases when the SNR of the input signal increases, and the proportion of the input signal of which noise is not eliminated increases when the SNR of the input signal decreases.

The method may further include estimating noise of the input signal using at least one of an MCRA algorithm, an IMCRA algorithm, and a minimum statistics algorithm.

The method may further include estimating the SNR of the input signal using at least one of an MMSE, an RMS error, a CMD, and an SPP.

Furthermore, in accordance with embodiments of the present disclosure, there is provided a method of eliminating noise, including: dividing an input signal into a signal having a high frequency component and a signal having a low frequency component; eliminating noise of the signal having the high frequency component based on a low resolution analysis algorithm; eliminating noise of the signal having the low frequency component based on a high resolution analysis algorithm; and synthesizing the signal having the high frequency component of which noise is eliminated with the signal having the low frequency component of which noise is eliminated.

The eliminating of noise of the signal having the high frequency component may include: determining a gain and a correction value of the gain using an SNR of the input signal; acquiring a corrected gain by applying the determined correction value to the determined gain; and acquiring an output signal by applying the corrected gain to the input signal, wherein a proportion of the input signal of which noise is eliminated in the output signal and a proportion of the input signal of which noise is not eliminated in the output signal are changed based on the determined correction value.

The eliminating of noise of the signal having the low frequency component may include estimating noise from an initial signal of the input signal and eliminating noise of the signal having the high frequency component using the estimated noise.

BRIEF DESCRIPTION OF THE DRAWINGS

These and/or other aspects of the disclosure will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings of which:

FIG. **1** is a block diagram of an apparatus for eliminating noise according to embodiments of the present disclosure;

FIG. **2** illustrates an example of waveforms of signals having noise;

FIGS. **3** through **5** are graphs showing the relationship between a correction value and a signal to noise ratio (SNR);

FIG. **6** is a block diagram of an apparatus for eliminating noise according to embodiments of the present disclosure;

FIG. **7** is a graph for explaining high resolution analysis and low resolution analysis of frequencies;

FIG. **8** is a block diagram of a sound recognition apparatus according to embodiments of the present disclosure;

FIG. **9** is a graph showing frequency conversion using a frequency conversion unit;

FIG. **10** is a view of an internal structure of a vehicle;

FIG. **11** is a block diagram of a sound recognition apparatus according to embodiments of the present disclosure installed in the vehicle;

FIG. **12** is a block diagram of a sound recognition apparatus according to embodiments of the present disclosure installed in the vehicle;

FIG. **13** is a flowchart of a method of eliminating noise according to embodiments of the present disclosure; and

FIG. **14** is a flowchart of a method of eliminating noise according to embodiments of the present disclosure.

DETAILED DESCRIPTION

Reference will now be made in detail to the embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

It is understood that the term "vehicle" or "vehicular" or other similar term as used herein is inclusive of motor vehicles in general such as passenger automobiles including sports utility vehicles (SUV), buses, trucks, various commercial vehicles, watercraft including a variety of boats and ships, aircraft, and the like, and includes hybrid vehicles, electric vehicles, plug-in hybrid electric vehicles, hydrogen-powered vehicles and other alternative fuel vehicles (e.g., fuels derived from resources other than petroleum). As referred to herein, a hybrid vehicle is a vehicle that has two or more sources of power, for example both gasoline-powered and electric-powered vehicles.

Additionally, it is understood that one or more of the below methods, or aspects thereof, may be executed by at least one controller. The term "controller" may refer to a hardware device that includes a memory and a processor. The memory is configured to store program instructions, and the processor is configured to execute the program instructions to perform one or more processes which are described further below. Moreover, it is understood that the below methods may be executed by an apparatus comprising the control unit, whereby the apparatus is known in the art to be suitable for eliminating noise and/or embodying a sound recognition apparatus.

Furthermore, the controller of the present disclosure may be embodied as non-transitory computer readable media on a computer readable medium containing executable program instructions executed by a processor, controller or the like. Examples of the computer readable mediums include, but are not limited to, ROM, RAM, compact disc (CD)-ROMs, magnetic tapes, floppy disks, flash drives, smart cards and optical data storage devices. The computer readable recording medium can also be distributed in network coupled computer systems so that the computer readable media is stored and executed in a distributed fashion, e.g., by a telematics server or a Controller Area Network (CAN).

Hereinafter, a plurality of elements are distinguished from a single element so as to explain an apparatus and method of eliminating noise, a sound recognition apparatus using the apparatus and a vehicle equipped with the sound recognition apparatus. However, elements to be described are distinguished for convenience of explanation, and such classification does not mean that the elements should be physically separated from each other. Furthermore, the elements to be described may be subdivided or combined.

Hereinafter, an apparatus for eliminating noise will be described with reference to FIGS. **1** through **7**.

FIG. **1** is a block diagram of an apparatus for eliminating noise according to embodiments of the present disclosure, and FIG. **2** illustrates an example of waveforms of signals having noise.

According to embodiments of the present disclosure shown in FIG. **1**, an apparatus **10** for eliminating noise may include a noise component estimation unit **11**, a gain acquisition unit **12**, and a gain application unit **19**. Referring to FIGS. **1** and **2**, the apparatus **10** for eliminating noise may receive an input signal I (I=S+N) in which an original signal and noise N are mixed from an external device such as a microphone, and may output signals O in which noise N is eliminated or attenuated from the received input signal I using the noise component estimation unit **11**, the gain acquisition unit **12**, and the gain application unit **19**.

The noise component estimation unit **11** of the apparatus **10** for eliminating noise may receive the input signal I in which the original signal S and the noise N are mixed from the external device and may acquire estimated noise (EN) from the input signal I in which the original signal S and the noise N are mixed. In detail, the noise component estimation unit **11** may estimate only the EN from among frequency components of the input signal I.

The noise component estimation unit **11** may estimate a noise component from the input signal I using various algorithms that may be considered by one of ordinary skill in the art. For example, the noise component estimation unit **11** may acquire the EN from the input signal I using various algorithms, such as a minima controlled recursive averaging (MCRA) algorithm, an improved minima controlled recursive averaging (IMCRA) algorithm, and a minimum statistics algorithm. In addition, the noise component estimation unit **11** may use various mathematical or statistical algorithms for estimating a noise signal from the input signal I. In embodiments, the noise component estimation unit **11** may also estimate the noise component using a speech presence probability (SPP) regarding whether a frequency component is close to the sound. For example, the noise component estimation unit **11** may also estimate the noise using the SPP in the MCRA algorithm.

In embodiments, the noise component estimation unit **11** may also divide the input signal I into a plurality of bands and then may separately estimate the noise component in each of the divided plurality of bands. Also, in embodiments, the noise component estimation unit **11** may also estimate the noise component from the entire input signal I.

The EN acquired by the noise component estimation unit **11** may be transmitted to the gain acquisition unit **12**.

The gain acquisition unit **12** may acquire a gain G to be applied to the input signal I using the EN. In embodiments, the gain acquisition unit **12** may separately acquire the gain G in each of the divided bands of the input signal I. Further, in embodiments, the gain acquisition unit **12** may also acquire the gain G by calculating the gain G from the entire input signal I.

In embodiments shown in FIG. **1**, the gain acquisition unit **12** may include a signal to noise ratio (SNR) estimation unit **13**, a gain estimation unit **15**, a correction value determination unit **16**, and a gain correction unit **18**.

The SNR estimation unit **13** may receive the acquired EN from the noise component estimation unit **11** and may estimate the SNR using the received EN. Here, the SNR estimation unit **13** may receive the EN and the input signal I from the noise component estimation unit **11** and the external device and may estimate the SNR using the received EN and input signal I.

The SNR may be defined using the following Equation 1, for example. Hereinafter, the SNR defined as in Equation 1 will be described. However, the SNR is not limited to being defined as in Equation 1 but may be defined differently according to a designer.

$$SNR = c\log\left(\frac{S^2}{N^2}\right) \qquad \text{[Equation 1]}$$

S is an original signal with which noise N is not synthesized, N is noise, and SNR is an SNR. c is a constant that may be applied according to the user's selection. Here, N may be estimated noise (EN) that is estimated by the noise component estimation unit **11**. When the SNR is defined in this way, if there is much noise N in the original signal S, the SNR may have a relatively small value, and if there is less noise N in the original signal S, the SNR may have a relatively larger value.

When the SNR is defined in this way, the original signal S with which the noise N is not synthesized should first be acquired. Thus, the SNR estimation unit **13** may acquire the EN estimated by the noise component estimation unit **11** and SNR SNR_EST estimated using the following Equation 2 and may substitute for an original SNR.

$$SNR_{EST} = c\log\left(\frac{I^2}{N^2}\right), \text{ wherein } I = S + N \qquad \text{[Equation 2]}$$

I is an input signal in which the above-described original signal S and the noise N are mixed, and SNR_EST is an estimated SNR.

The SNR estimation unit **13** may acquire the estimated SNR SNR_EST using the above-described Equation 2.

In embodiments, the SNR estimation unit **13** may estimate the SNR by using a minimum mean square error (MMSE) in which a mean square error (MSE) is minimized, may estimate the SNR using a root mean square (RMS) error, or may estimate the SNR using a cumulative minimum distance (CMD).

In embodiments, the SNR estimation unit **13** may acquire the SPP or may estimate the SNR using the acquired SPP. To this end, the SNR estimation unit **13** may further include an SPP estimation unit **14** that calculates and estimates an SPP. The SPP estimation unit **14** may estimate and acquire the SPP using various methods that may be considered by one of ordinary skill in the art. When the SPP is estimated by the SPP estimation unit **14**, the SNR estimation unit **13** may correct the estimated SNR SNR_EST based on the SPP. The SPP estimation unit **14** may be omitted depending on the embodiments.

The estimated SNR SNR_EST acquired by the SNR estimation unit **13** may be transmitted to the gain estimation unit **15** and the correction value determination unit **16**. Also, the SPP acquired by the SPP estimation unit **14** of the SNR estimation unit **13** may be transmitted to the gain estimation unit **15**.

The gain estimation unit **15** may calculate and estimate a gain EG using the estimated SNR SNR_EST. In embodiments, the gain estimation unit **15** may also calculate and estimate the EG by further using the transmitted SPP as well as the estimated SNR SNR_EST.

The gain estimation unit **15** may also estimate the gain EG using a minimum mean-square error-short time spectral amplitude (MMSE-STSA) estimator, a minimum mean square error-log spectral amplitude (MMSE-LSA) estimator, or an optimally modified-log spectral amplitude (OM-LSA) estimator depending on the embodiments. In addition, the gain estimation unit **15** may also estimate the gain EG using various methods that may be considered by one of ordinary skill in the art.

The correction value determination unit **16** may determine a correction value α for correcting the estimated gain EG. In detail, the correction value determination unit **16** may determine the correction value α using the SNR. The SNR used in the correction value determination unit **16** may include the estimated SNR SNR_EST transmitted from the SNR estimation unit **13**. Hereinafter, both the SNR and the estimated SNR SNR_EST may be referred to as an SNR SNR_EST.

FIGS. **3** through **5** are graphs showing the relationship between a correction value and an SNR. In FIGS. **3** through **5**, the x-axis represents an SNR SNR_EST, and the y-axis represents a correction value α for correcting the estimated gain EG. The correction value α may be a particular value in the range from 0 to 1. In FIGS. **3** through **5**, the correction value α that corresponds to each of points a**1** through a**6** of the y-axis is a value that is greater than 0 and less than 1. In FIGS. **3** through **5**, the correction value α does not have a value of 0. However, the correction value α may also be 0 depending on the embodiments. Also, the correction value α does not have a value of 1. However, the correction value α may also be 1 depending on the embodiments.

Referring to FIG. **3**, when the SNR SNR_EST is less than a predetermined first SNR R**1**, the correction value determination unit **16** may determine a uniform lower limit value a**1** as the correction value α for correcting the estimated gain EG. In other words, the correction value α with respect to the SNR SNR_EST that is less than the first SNR R**1** may be uniform.

Also, when the SNR SNR_EST is greater than a predetermined second SNR R**2**, the correction value determination unit **16** may determine a uniform upper limit value a**2** as the correction value α for correcting the estimated gain EG. In other words, when the SNR SNR_EST is greater than the second SNR R**2**, the correction value α may be uniform. When the SNR SNR_EST is greater than the second SNR R**2**, it may mean that less noise N is present in the input signal I. Thus, the correction value α may be determined as 1 or a value that is close to 1.

Referring to FIG. **3**, when the SNR SNR_EST is between the first SNR R**1** and the second SNR R**2**, the correction value determination unit **16** may determine the correction value α in proportion to a value of the SNR SNR_EST. In other words, the SNR, SNR_EST and the correction value α may have a linear relationship I**1** in the range of a first value R**1** and a second value R**2**. Here, the correction value α may have a value in the range from the lower limit value a**1** and the upper limit value a**2**.

Referring to FIG. **4**, when the SNR SNR_EST is less than a third SNR R**3**, the correction value determination unit **16** may determine a uniform lower limit value a**3** as the correction value α for correcting the estimated gain EG, and when the SNR SNR_EST is greater than a predetermined fourth SNR R**4**, the correction value determination unit **16** may determine a uniform upper limit value a**4** as the correction value α for correcting the estimated gain EG. When the SNR SNR_EST is between the third SNR R**3** and the fourth SNR R**4**, the correction value determination unit **16** may determine the correction value α by applying the SNR SNR_EST to a predetermined exponential function I**2**.

Also, referring to FIG. **5**, when the SNR SNR_EST is less than a fifth SNR R**5**, the correction value determination unit **16** may determine a uniform lower limit value a**5** as the correction value α, and when the SNR SNR_EST is greater than a sixth SNR R**6**, the correction value determination unit **16** may determine an upper limit value a**6** as the correction value α, and when the SNR SNR_EST is between the fifth SNR R**5** and the sixth SNR R**6**, the correction value determination unit **16** may also determine the correction value α by applying the SNR SNR_EST to a predetermined log function I**3**.

In addition, the correction value determination unit **16** may determine the correction value α for correcting the estimated gain EG using various relationships between the SNR SNR_EST and the correction value α.

The above-described upper limit value a**1**, a**3** or a**5** and the above-described lower limit value a**2**, a**4** or a**6** may be arbitrarily determined by a designer of the apparatus **10** for eliminating noise or a user who uses the apparatus **10** for eliminating noise. The upper limit value a**1**, a**3** or a**5** and the lower limit value a**2**, a**4** or a**6** may also be fixed values. In addition, the upper limit value a**1**, a**3** or a**5** and the lower limit value a**2**, a**4** or a**6** may be variable values depending on the embodiments. In other words, the designer or the user may change the upper limit value a**1**, a**3** or a**5** and the lower limit value a**2**, a**4** or a**6**, thereby changing the correction value α determined according to the SNR SNR_EST.

In embodiments, the correction value determination unit **16** may determine the correction value α by further using the SNR SNR_EST and a separately input set value **17**. In this case, the correction value determination unit **16** may first determine the relationship between the SNR SNR_EST and the correction value α according to the set value **17** and subsequently may determine the correction value α by applying the input SNR SNR_EST to the relationship between the above-described SNR SNR_EST and the correction value α.

The set value **17** may refer to a value that indicates a selectable situation. Thus, the number of selectable set values **17** may correspond to the number of selectable situations. The set value **17** may be a value that indicates settings or performance of a sound recognition apparatus to which the apparatus **10** for eliminating noise may be applied. For example, the set value **17** may be a value that indicates the sound recognition apparatus that indicates whether noise is further eliminated or is not eliminated from an output signal o by further using another apparatus for eliminating noise.

The correction value determination unit **16** may change the relationship between the correction value and the SNR according to the set value **17**. For example, the correction value determination unit **16** may also change a function regarding the relationship between the correction value and the SNR according to the set value **17** and may also change a lower limit value a**1**, a**3** or a**5** or an upper limit value a**2**, a**4** or a**6** of the correction value α according to the set value **17**. In other words, the correction value determination unit **16** may acquire various correction values α that are appropriate for several situations according to the set value **17**.

In detail, for example, if the set value **17** that indicates a sound recognition apparatus that further uses another apparatus for eliminating noise is input to the correction value determination unit **16**, the correction value determination unit **16** may acquire the correction value α after changing the above-described lower limit value a**1**, a**3** or a**5** to be relatively smaller according to the input set value **17**. If there is much noise N in the input signal I, the SNR SNR_EST is low and the output signal o is transmitted to the sound recognition apparatus that further uses another apparatus for eliminating noise, the correction value α may have a relatively small value. Thus, as will be described later, the proportion of an original input signal I that is not distorted in the output signal o is increased. If the proportion of the original input signal that is not distorted increases, the proportion of an original signal that is not distorted in the input signal I increases so that more original signals may be output without distortion. Thus, an error of sound recognition of the sound recognition apparatus may be reduced.

If the set value **17** that indicates the sound recognition apparatus that does not further use another apparatus for eliminating noise is input to the correction value determination unit **16**, the correction value determination unit **16** may acquire the correction value α after changing the above-described lower limit value a**1**, a**3** or a**5** to be relatively smaller according to the input set value **17**.

The set value **17** may be stored in a separate storage apparatus, such as a semiconductor storage apparatus or a magnetic disk storage apparatus. The correction value determination unit **16** may determine the relationship between the SNR SNR_EST and the correction value α by calling the set value **17** from the separate storage apparatus.

The gain correction unit **18** may correct the gain EG transmitted by the gain estimation unit **15** using the correction value α determined by the correction value determination unit **16** and may output the corrected gain CG. The gain correction unit **18** may correct the gain using the following Equation 3.

$$cG=a(SNR,T)*G+(1.0-a(SNR,T)) \qquad \text{[Equation 3]}$$

cG is a corrected gain, SNR is an SNR SNR_EST, T is a set value, and a(SNR, T) is a correction value α determined by the SNR SNR_EST and the set value T. G is a gain EG estimated by the gain estimation unit **15**. According to Equation 3, when the correction value α is 1 or a value that is close to 1, the corrected gain cG output from the gain correction unit **18** will be the same as or similar to the gain EG estimated by the gain estimation unit **15**. If the correction value α is 0 or a value that is close to 0, the corrected gain cG output from the gain correction unit **18** may be 1 or a value that is close to 1.

The gain application unit **19** may acquire the output signal o using the corrected gain CG by the gain correction unit **18** and the input signal I. The gain application unit **19** may generate the output signal o to which the gain is applied, using the following Equation 4.

$$O=cG*I=[a*G+(1.0-a)]*I=a*G*I+(1.0-a)*I \qquad \text{[Equation 4]}$$

o is an output signal and cG is a corrected gain. α is a corrected value, and G is an estimated gain EG. The correction value α may be determined by the SNR SNR_EST and the set value T. Here, a*G*I at a side farthest to the right is a proportion of the input signal from which the noise N corrected by the estimated gain EG is eliminated, and (1.0−a)*I is a proportion of the original input signal I that is not distorted.

According to Equation 4, the proportion of the input signal from which the noise N is eliminated, and the proportion of the original input signal I may be determined according to the size of the correction value α. If the correction value α is 1 or a value that is close to 1, the input signal from which the noise N is eliminated will be output as the output signal o from the gain application unit **19**. If the correction value α is 0 or a value that is close to 0, the original input signal I that is not distorted will be output as the output signal o from the gain application unit **19**.

Referring to FIGS. **3** through **5**, the correction value α may be determined according to the SNR SNR_EST and the set value **17**. Thus, the proportion of the input signal from which the noise N is eliminated and the proportion of the original input signal I may be determined according to the SNR SNR_EST or the set value **17**. In more detail, the proportion of the input signal from which the noise N is eliminated, and the proportion of the original input signal I may be determined depending on whether there is much noise N in the input signal I or according to settings or performance of the sound recognition apparatus to which the apparatus **10** for eliminating noise.

If there is less noise N in the input signal I and the SNR SNR_EST is large, the correction value α may be determined as a value that is close to the upper limit value a**2**, a**4** or a**6**. In this case, the correction value α may also be determined as 1 or a value that is close to 1. Then, since the correction value α is increased, the proportion of the input signal from which the noise N is eliminated in the output signal o is relatively increased, and the proportion of the original input signal I that is not distorted is relatively decreased. If the SNR SNR_EST is large, the input signal to which the estimated gain EG is applied is a signal from which the noise N is eliminated and which is hardly distorted, and the proportion of the input signal from which the noise N is eliminated increases, so that distortion of the input signal I may be minimized and the optimized output signal o may be obtained.

When there is much noise N in the input signal I and the SNR SNR_EST is small, the correction value α may be determined as a value that is close to the lower limit value a**1**, a**3** or a**5**. In this case, since the correction value α decreases, the proportion of the input signal from which the noise N is eliminated in the output signal o will be relatively decreased, and the proportion of the original input signal I that is not distorted will be relatively increased. If the SNR SNR_EST is small, much noise N of the input signal to which the estimated gain EG is applied is eliminated so that distortion of a sound signal increases. Thus, the proportion of the original input signal I that is not distorted increases so that the output signal o in which distortion is minimized may be obtained.

If the correction value α is not applied to the estimated gain EG, there is much noise N in the input signal I and the SNR SNR_EST is small, only the input signal from which the noise N is eliminated is output as the output signal o so that distortion of the input signal I may be increased.

However, as described above, if an appropriate correction value α is applied according to the SNR SNR_EST or settings or performance of the sound recognition apparatus, distortion of the input signal I may be minimized, and the optimized output signal o may be obtained.

The noise component estimation unit **11**, the gain acquisition unit **12** and the gain application unit **19** described above may be performed by separate processors that are physically separated from each other or using one processor. The processor may be programmed to perform a function of the noise component estimation unit **11**, the gain acquisition unit **12** or the gain application unit **19**. The processor may be implemented by one or two or more semiconductors.

FIG. **6** is a block diagram of an apparatus for eliminating noise according to embodiments of the present disclosure, and FIG. **7** is a view for explaining a high resolution analysis algorithm and a low resolution analysis algorithm of frequencies.

As illustrated in FIG. **6**, an apparatus **20** for eliminating noise may include a frequency band division unit **21**, a synthesis unit **22**, a high frequency noise processing unit **30**, and a low frequency noise processing unit **40**. In detail, the apparatus **20** for eliminating noise according to embodiments of the present disclosure may classify an input signal I according to frequency band and then may eliminate noise N by applying different methods in each frequency band.

The frequency band division unit **21** may divide the input signal I into a signal H having a high frequency component and a signal L having a low frequency component. The input signal I may be divided into the signal H having the high frequency component and the signal L having the low frequency component. The frequency band division unit **21** may divide the input signal I into the signal H having the high frequency component and the signal L having the low frequency component using a predetermined reference value. For example, as illustrated in FIG. **7**, the predetermined reference value may include 4 kHz. In this case, the frequency band division unit **21** may divide a component of a frequency less than 4 kHz into the signal L having the low frequency component and a component of a frequency more than 4 kHz into the signal H having the high frequency component. In this way, the predetermined reference value may be arbitrarily determined according to the designer's or the user's selection.

The signal H having the high frequency component may be transmitted to a high frequency noise processing unit **30**, and the signal L having the low frequency component may be transmitted to a low frequency noise processing unit **40**.

The high frequency noise processing unit **30** and the low frequency noise processing unit **40** may eliminate noise of a signal having a high frequency component and noise of a signal having a low frequency component in the same manner or using different methods. For example, both the high frequency noise processing unit **30** and the low frequency noise processing unit **40** may eliminate noise using a method performed by the high frequency noise processing unit **30** that will be described later or a method performed by the low frequency noise processing unit **40** that will be described later. Hereinafter, embodiments in which the high frequency noise processing unit **30** and the low frequency noise processing unit **40** eliminate noise using different methods will be described. However, this does not mean that the high frequency noise processing unit **30** and the low frequency noise processing unit **40** can eliminate noise only according to the embodiments.

The high frequency noise processing unit **30** may eliminate noise N of a signal H having a high frequency component. In embodiments, the high frequency noise processing unit **30** may eliminate the noise N according to a low resolution analysis algorithm. Referring to FIG. **7**, the low resolution analysis algorithm may be an algorithm that is set to divide a high frequency component into a plurality of frequency bands **c1** through **c3** of which each bandwidth becomes relatively wide and to eliminate the noise N in each of the plurality of divided frequency bands **c1** through **c3**.

The high frequency noise processing unit **30** may include a first noise component estimation unit **31** and a noise elimination unit **32**.

The first noise component estimation unit **31** may estimate only a noise component from the signal H having the high frequency component transmitted from the frequency band division unit **21** in each of the relatively wide frequency bands **c1** through **c3**. The first noise component estimation unit **31** may estimate the noise component from the signal H having the high frequency component using various algorithms that may be considered by one of ordinary skill in the art. The first noise component estimation unit **31** may estimate the noise N using an initial signal having no original signal, such as a sound, i.e., the noise N, or an initial signal of which the main component is the noise N. The first noise component estimation unit **31** may estimate and determine the initial signal as noise. In this case, the first noise component estimation unit **31** may calculate an average energy level from the initial signal for a predetermined period and may estimate the calculated average energy level as the noise N.

The noise elimination unit **32** may eliminate the noise N in each of the frequency bands **c1** through **c3** of the signal H having the high frequency component transmitted from the frequency band division unit **21**. The noise elimination unit **32** may eliminate the noise N from the input signal I by eliminating the initial signal estimated as the noise N from the input signal I. The noise elimination unit **32** may eliminate the noise N by eliminating the estimated noise of the average energy level calculated from the initial signal from the signal H having the high frequency component. The noise elimination unit **32** may eliminate the noise N from the signal H having the high frequency component using various algorithms. For example, the noise elimination unit **32** may eliminate the noise N from the signal H having the high frequency component using spectral subtraction or a Wiener filter.

A signal o**1** of which noise is eliminated by the high frequency noise processing unit **30**, may be transmitted to the synthesis unit **22** and may be synthesized with a signal o**2**, of which noise transmitted from the low frequency noise processing unit **40** is eliminated.

The low frequency noise processing unit **40** may eliminate the noise N of the signal L having the low frequency component. In embodiments, the low frequency noise processing unit **40** may eliminate the noise N according to the high resolution analysis algorithm. Referring to FIG. **7**, the low frequency noise processing unit **40** may divide the low frequency component into a plurality of frequency bands **c4** through **c10** of which each bandwidth becomes relatively narrow, according to the high resolution analysis algorithm and then may eliminate the noise N in each of the plurality of frequency bands **c4** through **c10**. In other words, the low frequency noise processing unit **40** may divide the frequency component into a plurality of frequency bands having a relatively larger number than that of high frequency noise processing units **30** and may eliminate the noise N in each of the plurality of divided frequency bands **c4** through **c10**.

The low frequency noise processing unit **40** may include a second noise component estimation unit **41**, a gain acquisition unit **42**, and a gain application unit **49**.

The second noise component estimation unit **41** may estimate only a noise component from among frequency components of the signal L having the low frequency component. Here, the second noise component estimation unit **41** may estimate the noise component in each band. The second noise component estimation unit **41** may estimate the noise component from the signal L having the low frequency component using various algorithms that may be considered by one of ordinary skill in the art, such as an MCRA algorithm, an IMCRA algorithm, and a minimum statistics algorithm. In addition, the second noise component estimation unit **41** may estimate the noise component from the signal L having the low frequency component using various mathematical or statistical algorithms for estimating the noise signal. Also, the second noise component estimation unit **41** may estimate the noise component using an SPP regarding whether the frequency component is close to the sound.

The gain acquisition unit **42** may acquire a gain to be applied to the signal L having the low frequency component using estimated noise. In embodiments shown in FIG. **1**, the gain acquisition unit **42** may include an SNR estimation unit **43**, a gain estimation unit **45**, a correction value determination unit **46**, and a gain correction unit **48**.

The SNR estimation unit **43** may acquire an estimated SNR using the estimated noise acquired by the second noise component estimation unit **41**. The SNR estimation unit **43** of FIG. **6** may be the same as the SNR estimation unit **13** illustrated in FIG. **1**.

In embodiments, the SNR estimation unit **43** may use an MMSE, an RMS error, or a CMD so as to estimate the SNR. Also, the SNR estimation unit **43** may acquire the SPP or may estimate the SNR using the acquired SPP.

The gain estimation unit **45** may calculate and estimate a gain using the estimated SNR. In embodiments, the gain estimation unit **45** may also calculate and estimate by further using the estimated SNR and the SPP.

The gain estimation unit **45** may use a MMSE-STSA estimator, a MMSE-LSA estimator, or an OD-LSA estimator so as to estimate the gain, depending on the embodiments. In addition, the gain estimation unit **15** may use various methods that may be considered by one of ordinary skill in the art so as to estimate the gain.

The correction value determination unit **46** may determine a correction value for correcting the estimated gain using the SNR. Here, the SNR may include the estimated SNR transmitted from the SNR estimation unit **43**. The correction value determination unit **46** may determine the correction value using only the SNR or using both the SNR and a set value **47**.

The correction value determination unit **46** may determine the correction value using the relationship between the correction value and the SNR that have been described with reference to FIGS. **3** through **5**. As illustrated in FIGS. **3** through **5**, if the acquired SNR is less than a predetermined value R**1**, R**3** or R**5** or greater than a predetermined value R**2**, R**4** or R**6**, correction values a**1** through a**6** may be uniform. The correction value and the SNR may have the relationship of a linear function I**1**, an exponential function I**2** or a log function I**3** in the range from the predetermined values R**1** and R**2**, R**3** and R**4**, or R**5** and R**6**. In addition, the correction value determination unit **46** may determine the correction value for correcting the estimated gain using various relationships between the SNR and the correction value.

Also, the correction value determination unit **46** may determine the correction value by further using the set value **47**. In this case, the correction value determination unit **16** may first determine the relationship between the SNR and the correction value to be used according to the set value **47**, and may subsequently determine the correction value using the relationship between the SNR and the correction value, as described above. Here, the set value **47** may be the same as the set value **17** described with reference to FIG. **1**. In detail, the set value **47** may refer to a value that indicates a selectable situation and may also include a value that indicates settings or performance of a sound recognition apparatus to which the apparatus **10** for eliminating noise may be applied. The relationship between the correction value and the SNR may be changed according to the set value **47**. In this case, a function regarding the relationship between the correction value and the SNR may be changed according to the set value **47**, and a lower limit value a**1**, a**3** or a**5** or an upper limit value a**2**, a**4** or a**6** of the relationship between the correction value and the SNR illustrated in FIGS. **3** through **5** may be changed according to the set value **47**.

The gain correction unit **48** may correct and output the gain transmitted by the gain estimation unit **45** using the correction value determined by the correction value determination unit **46**. The gain correction unit **18** may correct the gain using the above-described Equation 3.

The gain application unit **49** may acquire the signal o**2** to be transmitted to the synthesis unit **22** using the gain corrected by the gain correction unit **48** and the signal L having the low frequency component. The gain application unit **49** may generate the signal o**2** to be transmitted to the synthesis unit **22** to which the gain is applied using the above-described Equation 4. Thus, the signal o**2** output from the gain application unit **49** may be a signal having a high proportion of the signal L having the low frequency component or a signal having a high proportion of the signal of which noise is eliminated from the signal L having the low frequency component according to the correction value. The signal output from the gain application unit **49** may be transmitted to the synthesis unit **22**.

The synthesis unit **22** may synthesize the signal o**1** output from the high frequency noise processing unit **30** with the signal o**2** output from the low frequency noise processing unit **40** and may acquire the output signal o. The output signal o may be a signal of which noise N is eliminated using different methods depending on whether the output signal o has a high frequency or a low frequency.

The frequency band division unit **21**, the high frequency noise processing unit **30**, the low frequency noise processing unit **40**, and the synthesis unit **22** of the apparatus **20** for eliminating noise described above may be performed using separate processors that are physically separated from each other or using one processor. The processor may be programmed to perform a function of the frequency band division unit **21**, the high frequency noise processing unit **30**, the low frequency noise processing unit **40** or the synthesis unit **22**. The processor may be implemented by one or two or more semiconductors.

Hereinafter, a sound recognition apparatus that uses an apparatus for eliminating noise will be described with reference to FIGS. **8** and **9**.

FIG. **8** is a block diagram of a sound recognition apparatus according to embodiments of the present disclosure.

Referring to FIG. **8**, a sound recognition apparatus **50** may include a sound input unit **51**, a frequency conversion unit **52**, a frequency band division unit **53**, a noise elimination unit **54**, and an inverter **58**.

The sound input unit **51** may receive a voice or sound that is a wave generated when a human being speaks or an object vibrates. The sound input unit **51** may generate and output an electrical signal corresponding to a frequency of the voice or sound by vibrating according to the frequency of the voice or sound. Here, the generated electrical signal may include an analog signal. Also, the generated electrical signal may be a signal in a time-domain. The electrical signal output from the sound input unit **51** may be transmitted to the frequency conversion unit **52**. If necessary, the electrical signal output from the sound input unit **51** may be transmitted to the frequency conversion unit **52** using an amplifier or an analog-to-digital (A/D) converter.

FIG. **9** is a graph showing frequency conversion using a frequency conversion unit.

As illustrated in FIG. **9**, the frequency conversion unit **52** may convert an input signal J in the time-domain into signals f**1** through f**3** in a frequency-domain. The frequency conversion unit **52** may convert the signal J in the time-domain into the signals f**1** through f**3** using a fast Fourier transform (FFT). The frequency conversion unit **52** may also be omitted depending on the embodiments.

The frequency band division unit **53** may divide the signals f**1** through f**3** in the frequency-domain into a signal H having a high frequency component and a signal L having a low frequency component, may transmit the signal H having the high frequency component to a high frequency noise processing unit **55** of the noise elimination unit **54**, and may transmit the signal L having the low frequency component to a low frequency noise processing unit **56** of the noise elimination unit **54**. The frequency band division unit **53** may also be omitted depending on the embodiments.

The noise elimination unit **54** may include the high frequency noise processing unit **55**, the low frequency noise processing unit **56**, and the synthesis unit **57**. The noise elimination unit **54** may be the noise elimination apparatus **10** shown in FIG. **1**, depending on the embodiments. In this case, the high frequency noise processing unit **55** and the synthesis unit **57** may be omitted from the noise elimination unit **54**, and the low frequency noise processing unit **56** may process both the signal H having the high frequency component and the signal L having the low frequency component.

The high frequency noise processing unit **55** may eliminate noise N of a signal H having a high frequency component and may transmit a signal o**1** from which the noise N is eliminated to the synthesis unit **57**. In the embodiments, the high frequency noise processing unit **55** may eliminate the noise N of the signal H having the high frequency component according to the low resolution analysis algorithm, as illustrated in FIG. **7**. In this case, the high frequency noise processing unit **55** may estimate a noise component from the signal H having the high frequency component transmitted from the frequency band division unit **53** and may eliminate noise estimated in each of the frequency bands **c1** through **c3** of the signal H having the high frequency component. The high frequency noise processing unit **55** may estimate noise by calculating an average energy level from an initial signal and may eliminate the noise N from the signal H having the high frequency component according to the result of estimation. The high frequency noise processing unit **55** may use spectral subtraction or a Wiener filter so as to eliminate the noise N.

The low frequency noise processing unit **56** may eliminate the noise N of the signal L having the low frequency component and may transmit a signal o**2** from which the noise N is eliminated to the synthesis unit **57**. In embodiments, the low frequency noise processing unit **56** may eliminate the noise N of the signal L having the low frequency component according to the high resolution analysis algorithm, as illustrated in FIG. **7**. The low frequency noise processing unit **56** may eliminate the noise N using the noise component estimation unit **11** or **41**, the gain acquisition unit **12** or **42**, and the gain application unit **19** or **49** that have been described with reference to FIGS. **1** and **6**. The noise component estimation unit **11** or **41**, the gain acquisition unit **12** or **42**, and the gain application unit **19** or **49** that are used in the low frequency noise processing unit **56** may be the same as those described above or slightly modified according to needs.

The synthesis unit **57** may synthesize the signal o**1** output from the high frequency noise processing unit **55** with the signal o**2** output from the low frequency noise processing unit **56** and may acquire an output signal o.

The inverter **58** may invert the signal o output from the synthesis unit **57** and may generate a speech signal s. The inverter **58** may perform inversion of the signal o output to the synthesis unit **57** using an inverse fast Fourier transform (IFFT).

The acquired speech signal s may be transmitted to the output unit **59**, such as a speaker, may be output to the outside or may be transmitted to a controller **61** of a device **60** to be controlled, such as a vehicle. The controller **61** may be configured of a separate microprocessor. The controller **61** may generate control instructions that correspond to the sound signal s, according to the speech signal s, may transmit the generated control instructions to a corresponding component in the device **60** to be controlled, and may control the device **60** to be controlled according to the user's sound instructions recognized by the sound recognition apparatus **50**.

Hereinafter, a vehicle equipped with a sound recognition apparatus that uses an apparatus for eliminating noise will be described. Hereinafter, a general four-wheeled motor vehicle will be described as an example of a vehicle equipped with the sound recognition apparatus that uses the apparatus for eliminating noise. The four-wheeled motor vehicle may include a small car, a van, a bus or a truck that may drive with four wheels. Also, the vehicle equipped with the sound recognition apparatus that uses the apparatus for eliminating noise is not limited to the general four-wheeled motor vehicle. Examples of the vehicle equipped with the sound recognition apparatus may include a three-wheeled motor vehicle, a two-wheeled motor vehicle such as a motorcycle, a motorized bicycle, a construction machine, a bicycle, a train capable of traveling on railroad tracks, or a ship capable of navigating a waterway.

FIG. **10** is a view of an internal structure of a vehicle.

As illustrated in FIG. **10**, a dashboard **200** may be disposed inside a vehicle **100**. The dashboard **200** refers to a panel that partitions off an interior of the vehicle **100** and an engine compartment and is disposed in front of a driver's seat **250** and a passenger seat **251** and in which various components required for driving are installed. The dashboard **200** may include an upper panel **201**, a center fascia **220**, and a gearbox **230**. The upper panel **201** of the dashboard **200** may be disposed under a windshield **202**, and a tuyere **113***a* of an air conditioning device **113** and a glove box or various indicators **140** may be installed on the upper panel **201**.

Also, a display device **110** for a vehicle, such as a navigation device, may be installed on the dashboard **200**. In more detail, the display device **110** for the vehicle may be installed at a top end of the center fascia **220**. The display device **110** for the vehicle may be buried in the dashboard **200** and may be installed at a top end of the center fascia **220** or may also be installed at the top end of the center fascia **220** using a supporting unit configured of a predetermined frame. One or two or more input units **133** and **134** for receiving the sound from a user, such as a driver or a passenger, may be disposed at a housing **111** of the display device **110** for the vehicle. The input units **133** and **134** may be implemented by a microphone.

The center fascia **220** (e.g., center console) of the dashboard **200** may be installed to be connected to the upper panel **201**, and input units **221** and **222**, such as physical buttons for controlling the vehicle, a radio device **116**, or a sound reproduction device **115**, such as a compact disc player, may be disposed at the center fascia **220** of the dashboard **200**. The center fascia **220** may be disposed between the driver's seat **250** and the passenger seat **251**.

In embodiments, various components including a microprocessor for controlling an electronic device in various vehicles including the display device **110** for the vehicle may be installed at an inner side of the dashboard **200**. Various components may include at least one from among at least one semiconductor chip, at least one switch, at least one integrated circuit (IC), at least one resistor, at least one volatile or nonvolatile memory, and at least one printed circuit board (PCB), which perform a function of the microprocessor. The semiconductor chip, the switch, the IC, the resistor, and the volatile or nonvolatile memory may be disposed on the PCB.

One or two or more input units **131** for receiving the sound from the driver or the passenger may be disposed at an inner side of an upper frame of the vehicle **100**. The input unit **131** may be implemented by a microphone. The input unit **131** may be electrically connected to the microprocessor that is disposed at the inner side of the dashboard **200** or the display device **110** for the vehicle **100** using a cable. Also, the input unit **131** may be electrically connected to the microprocessor disposed at the inner side of the dashboard **200** or the display device **110** for the vehicle **100** using a wireless communication network, such as Bluetooth or near field communication, and may transmit the sound received by the input unit **131** to the microprocessor.

Sun visors **121** and **122** may be installed at the inner side of the upper frame of the vehicle **100**. One or two or more input units **132** for receiving the sound from the driver or the passenger may be disposed at the sun visors **121** and **122**. The input unit **132** of the sun visors **121** and **122** may be implemented by the microphone. The input unit **132** of the sun visors **121** and **122** may be electrically connected to the microprocessor disposed at the inner side of the dashboard **200** or the display device **110** for the vehicle **100** in a wired or wireless manner and may transmit the sound signal received by the input unit **132** to the microprocessor. Also, a locking device **112** for locking a door **117** of the vehicle **100** may be disposed inside the vehicle **100**.

FIG. **11** is a block diagram of a sound recognition apparatus according to embodiments of the present disclosure installed in the vehicle **100**.

Referring to FIG. **11**, the vehicle **100** may include various components and devices **118** in the vehicle **100** including microphones **131** through **134** installed inside the vehicle **100** or the navigation device **110**, a frequency conversion unit **140**, a noise elimination unit **141**, an inverter **145**, a sound/text conversion unit **146**, a controller **147**, and a storage unit **148**.

Various components and devices **118** in the vehicle **100** may include various devices that may be used inside the vehicle **100** for driving or to provide the user with convenience, such as microphones **131** and **132**, a navigation device **110**, a locking device **112**, an air conditioning device **113**, a lighting device **114**, the sound reproduction device **115**, and the radio device **116**, as illustrated in FIG. **11**. The microphones **133** and **134** may be installed at the navigation device **110**.

The microphones **131** through **134** may receive the driver's or passenger's sound and may output an electrical signal corresponding to the received sound. The output electrical signal may be an analog signal. The output electrical signal may be transmitted to the frequency conversion unit **140**. The output electrical signal may be amplified by the amplifier or converted into a digital signal by the A/D converter before the output electrical signal is transmitted to the frequency conversion unit **140**. The output electrical signal may include a signal in a time-domain.

The microphones **131** through **134** may receive the sound of the user who is the driver or the passenger, an engine sound of the vehicle **100**, and various types of noise, such as a wind sound discharged from the tuyere **113***a* of the air conditioning device **113** or honks generated outside the vehicle **100**. Thus, the electrical signal output from the microphones **131** through **134** may further include various noise signals together with signals relating to the user's sound.

The microphones **131** and **132** may be disposed at the inner side of the upper frame of the vehicle **100** or the sun visors **121** and **122**, as illustrated in FIG. **10**. In addition, the microphones **131** and **132** may be installed in various positions of the interior of the vehicle **100**, such as on a steering handle. The positions in which the microphones **131** and **132** are installed may be positions in which the driver's or the passenger's sound is easily received. Furthermore, the microphones **133** and **134** may be previously installed in the navigation device **110**.

The frequency conversion unit **140** may convert the signal in the time-domain into the signal in the frequency-domain, as described with reference to FIG. **9**. The frequency conversion unit **140** may convert the signal in the time-domain into the signal in the frequency-domain using various methods including an FFT. The frequency conversion unit **140** may be omitted depending on embodiments.

The noise elimination unit **141** performs a function of eliminating noise from the signal in the frequency-domain in which the user's sound and noise inside the vehicle are mixed. The noise elimination unit **141** may include a noise component estimation unit **142**, a gain acquisition unit **143**, and a gain application unit **144**.

The noise component estimation unit **142** may acquire estimated noise transmitted from the microphones **131** through **134** or the frequency conversion unit **140**. The noise component estimation unit **142** may acquire the estimated noise by estimating the noise component using various algorithms that may be considered by one of ordinary skill in the art, such as an MCRA algorithm, an IMCRA algorithm, and a minimum statistics algorithm. In this case, the noise component estimation unit **142** may also estimate the noise component using the SPP.

The gain acquisition unit **143** may acquire an estimated SNR using the acquired estimated noise, may calculate and estimate a gain using the estimated SNR, may determine a correction value for correcting the estimated gain using the SNR, and may correct and output the estimated gain using the determined correction value.

The gain acquisition unit **143** may estimate the SNR using a method such as an MMSE, an RMS error, or a CMD. Also, the gain acquisition unit **143** may acquire the SPP and may also estimate the SNR using the acquired SPP.

The gain acquisition unit **143** may calculate the estimated gain using the estimated SNR. If necessary, the gain acquisition unit **143** may also calculate the estimated gain using the SPP. The gain acquisition unit **143** may estimate the gain using various methods that may be considered by one of ordinary skill in the art, such as an MMSE-STSA estimator, an MMSE-LSA estimator, or an OM-LSA estimator.

The gain acquisition unit **143** may determine the correction value for correcting the estimated gain using the estimated SNR. In this case, the gain acquisition unit **143** may acquire the correction value using the relationship between the correction value and the SNR or a predetermined set value. Here, the relationship between the correction value and the SNR may include several embodiments regarding the relationship between the correction value and the SNR that have been described with reference to FIGS. **3** through **5**. The set value may be a value that indicates a selectable situation, and the selectable situation may include settings or performance of the sound recognition apparatus inside the vehicle. The lower limit value a**1**, a**3** or a**5** or the upper limit value a**2**, a**4** or a**6** of the relationship between the correction value and the SNR shown in FIGS. **3** through **5** may be changed according to a set value.

The correction value may be determined to be large when the SNR is large, i.e., when there is less noise, and the correction value may be determined to be small when the SNR is small, i.e., when there is more noise. Also, a correction value obtained when the sound recognition apparatus inside the vehicle recognizes the sound by reflecting driving noise of the vehicle (hereinafter referred to as a first correction value) may be relatively smaller than a correction value obtained when the sound recognition apparatus inside the vehicle recognizes the sound by not reflecting the driving noise of the vehicle, as in an external server or terminal equipment such as a smartphone (hereinafter referred to as a second correction value). In particular, the first correction value may be determined to be the same as the second correction value when the SNR is large, and the first correction value may be determined to be smaller than the second correction value.

The gain acquisition unit **143** may correct the estimated gain using the determined correction value. The gain acquisition unit **143** may correct the gain according to the above-described Equation 3.

The gain application unit **144** may acquire an output signal by applying the corrected estimated gain acquired by the gain acquisition unit **143** to a signal transmitted by the microphones **131** through **134** or the frequency conversion unit **140**. The gain application unit **144** may acquire the output signal according to the above-described Equation 4.

In more detail, the gain acquisition unit **144** may increase the proportion of the signal of which noise is eliminated when the acquired correction value is closer to 1, and the gain acquisition unit **144** may increase the proportion of an original signal when the acquired correction value is closer to 0. Thus, if the sound recognition apparatus inside the vehicle recognizes the sound by reflecting the driving noise of the vehicle and the SNR of the sound signal is large, the correction value may be determined to be relatively small, and the gain acquisition unit **144** may synthesize the original signal with the signal of which noise is eliminated, so that the proportion of the original signal may be increased.

The signal output from the gain application unit **144** may be transmitted to the inverter **145**. The inverter **145** may invert the signal output from the noise elimination unit **141** using IFFT, thereby generating a sound signal of which noise is eliminated. The signal output from the inverter **145** may be transmitted to the controller **147** via the sound/text conversion unit **146** or directly to the controller **147**.

The sound/text conversion unit **146** may convert the sound into a text signal using various speech-to-text techniques and may transmit the converted text signal to the controller **147**. If the controller **147** is able to generate control instructions directly using the sound signal, the sound/text conversion unit **146** may also be omitted.

The controller **147** may generate corresponding control instructions using the sound signal or the text signal converted by the sound/text conversion unit **146**, may transmit the generated control instructions to corresponding components and devices to be controlled from among various components and devices **118** in the vehicle, thereby controlling the components and devices to be controlled. For example, when the driver gives sound instructions for lighting, the controller **147** may generate control signals corresponding to the sound instructions and then may transmit the generated control signals to the lighting device **114** and may turn on the lighting device **114**.

The storage unit **148** may store various data required to generate control signals for the components and devices in the vehicle. If necessary, the storage unit **148** may also store a history regarding the control signals generated by the controller **147**. The history regarding the control signals may also be used in learning of the sound recognition apparatus installed at the vehicle. In addition, the storage unit **168** may store various data or necessary settings.

The frequency conversion unit **140**, the noise elimination unit **141**, the inverter **145**, the sound/text conversion unit **146**, and the controller **147** described above may be implemented by a microprocessor installed in a particular position of the vehicle or the navigation device **110**. The microprocessor may be implemented as one or two or more semiconductor chips. The frequency conversion unit **140**, the noise elimination unit **141**, the inverter **145**, the sound/text conversion unit **146**, and the controller **147** may also be implemented by only one microprocessor or a plurality of microprocessors that are physically separated from each other. The microprocessor may be programmed so as to perform functions of the frequency conversion unit **140**, the noise elimination unit **141**, the inverter **145**, the sound/text conversion unit **146**, and the controller **147**.

FIG. **12** is a block diagram of a sound recognition apparatus according to embodiments of the present disclosure installed in the vehicle.

Referring to FIG. **12**, a vehicle **100** may include various components and devices **118** in the vehicle **100** including microphones **131** through **134** installed in the vehicle **100**, a frequency conversion unit **150**, a frequency band division unit **160**, a noise elimination unit **161**, an inverter **165**, a sound/text conversion unit **166**, a controller **167**, and a storage unit **168**.

Various components and devices **118** in the vehicle **100** may include microphones **131** and **132**, a navigation device **110**, a locking device **112**, an air conditioning device **113**, a lighting device **114**, a sound reproduction device **115**, and a radio device **116**, which are used for driving of the vehicle **100** or to provide a user with convenience, as illustrated in FIG. **12**.

The microphones **131** through **134** may receive the driver's or the passenger's sound and may output an electrical signal corresponding to the received sound, as described with reference to FIG. **11**. The output electrical signal may be an analog signal. The output electrical signal may be transmitted to the frequency conversion unit **150**. The output electrical signal may be amplified by an amplifier or converted into a digital signal by an A/D converter before the output electrical signal is transmitted to the frequency conversion unit **150**. The output electrical signal may include a signal in a time-domain. The microphones **131** through **134** may be installed in various positions of the vehicle **100**, such as an inner side of an upper frame of the vehicle **100**, sun visors **121** and **122**, a steering handle or the navigation device **110**.

The frequency conversion unit **150** may convert the signal in the time-domain into the signal in the frequency-domain, as described with reference to FIG. **9**. The frequency conversion unit **150** may convert the signal in the time-domain into the signal in the frequency-domain using various methods including an FFT. The frequency conversion unit **150** may also be omitted depending on the embodiments. The frequency conversion unit **150** may be implemented by a microprocessor installed in a particular position in the vehicle **100** or in the navigation device **110**.

The frequency band division unit **160** may divide the signal transmitted from the microphones **131** through **134** or the frequency conversion unit **150** into a signal having a high frequency component and a signal having a low frequency component using a predetermined reference value. Here, the predetermined reference value may be arbitrarily determined according to the designer's or the user's selection. The predetermined reference value may include 4 kHz, for example. The divided signal having the high frequency component and the signal having the low frequency component may be transmitted to the noise elimination unit **161**.

The noise elimination unit **161** may include a high frequency noise processing unit **162**, a low frequency noise processing unit **163**, and a synthesis unit **164**.

The signal having the high frequency component output from the frequency band division unit **160** may be transmitted to the high frequency noise processing unit **162**, and the signal having the low frequency component may be transmitted to the low frequency noise processing unit **163**.

The high frequency noise processing unit **162** may eliminate noise of the signal having the high frequency component. The high frequency noise processing unit **162** may eliminate the noise using a low resolution analysis algorithm. In more detail, the high frequency noise processing unit **162** may divide the signal having the high frequency component into relatively large frequency bands (see **c1** through **c3** of FIG. **7**), may estimate only a noise component in each of the frequency bands (see **c1** through **c3** of FIG. **7**), and may eliminate the noise in each of the frequency bands (see **c1** through **c3** of FIG. **7**) of the signal having the high frequency component. The high frequency noise processing unit **162** may estimate the noise using an initial signal in which no sound is spoken by the user from among signals input through the microphones **131** through **134** and may eliminate the estimated noise from the signals input through the microphones **131** through **134**. The initial signal may be configured of only noise, such as engine noise, or the main component of the initial signal may be noise. The high frequency noise processing unit **162** may calculate an average energy level from the initial signal for a predetermined period and may eliminate the calculated average energy level from the signals input through the microphones **131** through **134**, thereby eliminating the noise. The high frequency noise processing unit **162** may eliminate the noise from the signal having the high frequency component using an algorithm, such as spectral subtraction or a Wiener filter. The signal of which the noise is eliminated by the high frequency noise processing unit **162** may be transmitted to the synthesis unit **164**.

The low frequency noise processing unit **163** may eliminate noise of the signal having the low frequency component. In embodiments, the low frequency noise processing unit **163** may eliminate the noise according to the high resolution analysis algorithm. The low frequency noise processing unit **163** may divide the high frequency component into a plurality of frequency bands (see c**4** through c**10** of FIG. **7**) so that each of the plurality of frequency bands (see c**4** through c**10** of FIG. **7**) may be relatively narrow using the high resolution analysis algorithm and then may eliminate the noise in each of the frequency bands (see c**4** through c**10** of FIG. **7**).

The low frequency noise processing unit **163** may estimate the noise component from the signal having the low frequency component using various algorithms that may be considered by one of ordinary skill in the art, such as an MCRA algorithm, an IMCRA algorithm, and a minimum statistics algorithm. The low frequency noise processing unit **163** may estimate the noise component in each of the frequency bands. Also, the low frequency noise processing unit **163** may also estimate the noise component using the above-described SPP.

The low frequency noise processing unit **163** may acquire an estimated SNR using the estimated noise, may calculate a gain using the estimated SNR, may determine a correction value for correcting the estimated gain using the SNR, and may correct the estimated gain using the determined correction value.

The low frequency noise processing unit **163** may estimate the SNR using a method such as an MMSE, an RMS error, or a CMD. Also, the low frequency noise processing unit **163** may acquire the SPP and may also estimate the SNR using the acquired SPP.

The low frequency noise processing unit **163** may acquire an estimated gain using the estimated SNR. The low frequency noise processing unit **163** may acquire the estimated gain using the estimated SNR and the SPP.

The low frequency noise processing unit **163** may determine a correction value for correcting the estimated gain using the relationship between the correction value and the SNR and a set value. The relationship between the correction value and the SNR may be given, as illustrated in FIGS. **3** through **5**. For example, the correction value may be uniform in a predetermined range of the SNR and may have the relationship between the SNR and a linear function I**1**, an exponential function I**2** or a log function I**3** in a different range. The set value may be used to determine the relationship between the SNR and the correction value to be used to determine the correction value. The set value may include a value that indicates settings or performance of a sound recognition apparatus to which the apparatus **10** for eliminating noise may be applied.

The low frequency noise processing unit **163** may correct and output the above-described estimated gain using the determined correction value. Subsequently, the low frequency noise processing unit **163** may acquire an output signal by applying the corrected gain to the signal having the low frequency component and then may transmit the acquired output signal to the synthesis unit **164**. Correcting the estimated gain and applying the signal having the low frequency component may be calculated according to Equations 3 and 4.

The synthesis unit **164** may synthesize the signal output from the high frequency noise processing unit **162** with the signal output from the low frequency noise processing unit **163** so as to acquire a synthesized signal and may transmit the synthesized signal to the inverter **165**.

The inverter **165** may invert the signal output from the noise elimination unit **161** using an IFFT. Thus, a sound signal of which noise is eliminated may be acquired. The signal output from the inverter **165** may be transmitted to the controller **167** via the sound/text conversion unit **166** or directly to the controller **167** without passing through the sound/text conversion unit **166**.

The sound/text conversion unit **166** may convert the sound signal into a text signal using various speech-to-text techniques and may transmit the converted text signal to the controller **167**. If the controller **167** is able to generate control instructions directly using the sound signal, the sound/text conversion unit **166** may also be omitted.

The controller **167** may generate control instructions corresponding to the user's sound using the sound signal of which noise is eliminated, or the text signal, may transmit the generated control instructions to corresponding components and devices to be controlled from among various components and devices **118** in the vehicle **100**, thereby controlling the components and devices to be controlled.

The storage unit **168** may store various data required to generate control signals for various components and devices **118** in the vehicle **100** using the controller **167** or a history regarding the control signals generated by the controller **167**. In addition, the storage unit **168** may store various data or settings.

The frequency conversion unit **150**, the frequency band division unit **160**, the noise elimination unit **161**, the inverter **165**, the sound/text conversion unit **166**, and the controller **167** described above may be implemented by a microprocessor installed in a particular position in the vehicle **100** or in the navigation device **110**.

The microprocessor may be implemented by one or two or more semiconductor chips. The frequency conversion unit **150**, the frequency band division unit **160**, the noise elimination unit **161**, the inverter **165**, the sound/text conversion unit **166**, and the controller **167** may be implemented using only one microprocessor or using two or more microprocessors that are physically separated from each other.

Hereinafter, a method of eliminating noise according to embodiments of the present disclosure will be described with reference to FIGS. **13** and **14**.

Hereinafter, the method of eliminating noise that may be used in a sound recognition apparatus will be described. However, the method of eliminating noise is not performed by only the sound recognition apparatus. The method of eliminating noise may be used in various apparatuses that are required to eliminate noise. Also, the following sound recognition apparatus may be a sound recognition apparatus that is used in a three-wheeled or four-wheeled motor vehicle, a two-wheeled vehicle such as a motorcycle, a motorized bicycle, a construction machine, a bicycle, a train capable of traveling on railroad tracks, or a ship capable of navigating a waterway, as described above. However, embodiments of the present disclosure are not limited thereto. For example, a cellular phone, a personal digital assistant apparatus, a smartphone, a tablet personal computer (PC), a notebook computer, a navigation device or portable terminal equipment may also be an example of the sound recognition apparatus that uses the method of eliminating noise that will be described later. In addition, various types of devices that may be considered by one of ordinary skill in the art may be examples of the sound recognition apparatus that uses the method of eliminating noise that will be described later.

FIG. **13** is a flowchart of a method of eliminating noise according to embodiments of the present disclosure.

Referring to FIG. **13**, first, a signal in which a sound and noise are mixed may be input through a microphone (S**300**). The input signal may be amplified by an amplifier or converted into a digital signal by an A/D converter. The input signal may be a signal in a time-domain. In this case, the signal in the time-domain may be converted into a signal in a frequency-domain (S**301**). Conversion of the input signal into the frequency-domain may be performed using an FFT. The operation of converting the input signal into the signal in the frequency-domain may be omitted depending on the embodiments.

Subsequently, a noise component may be estimated from the input signal (S**302**). When the input signal is divided into a plurality of frequency bands, the noise component may be separately estimated in each of the plurality of frequency bands divided.

If the noise component is estimated, an SNR may be acquired or estimated using the estimated noise component (S**303**). The SNR or an estimated SNR may be acquired in each of the plurality of divided frequency bands. The SNR may be estimated using an MMSE, an RMS error, or a CMD. Also, the SNR may be estimated using an SPP.

If the SNR is acquired, a gain may be estimated using the SNR, and a correction value to be applied to the gain may be calculated (S**304**). Estimating the gain may be performed using an MMSE-STSA estimator, an MMSE-LSA estimator, or an OD-LSA estimator. The correction value may be determined using the relationship between the correction value and the SNR and the set value that have been described with reference to FIGS. **3** through **5** (S**305**).

The relationship between the correction value and the SNR may be set so that the correction value increases as the SNR increases. The relationship between the correction value and the SNR may also be set so that the correction value is uniform when the SNR is in a predetermined range.

The set value is a value that indicates a selectable situation, and the relationship between the correction value and the SNR may be changed according to the set value. Changing the relationship between the correction value and the SNR may be performed by changing a relationship function that indicates the relationship between the correction value and the SNR or by changing at least one of an upper limit value and a lower limit value of the selectable correction value. Here, the relationship function that indicates the relationship between the correction value and the SNR may have a shape of a linear function, an exponential function or a log function in a particular section, as illustrated in FIGS. **3** through **5**.

If the gain and the correction value are acquired, the gain may be corrected by applying the correction value to the gain, and an output signal may be acquired by applying the corrected gain to an input signal (S**306**). In embodiments, when the correction value is 1 or a value that is close to 1, the proportion of the signal of which the noise is eliminated in the output signal may be further increased, and when the correction value is a value that is close to 0, the proportion of the signal which is originally input and of which noise is not eliminated in the output signal may be further increased.

The output signal may be inverted using an IFFT (S**307**). A signal having a sound corresponding to the output signal may be acquired using an IFFT. The signal having the acquired sound may be a signal of which the noise is eliminated, a signal of which the noise is not eliminated, or a signal of which a part of the noise is eliminated, depending on the correction value.

FIG. **14** is a flowchart of a method of eliminating noise according to embodiments of the present disclosure.

Referring to FIG. **14**, first, a signal in which a sound and noise are mixed may be input through a microphone (S**310**). The input signal in which the sound and the noise are mixed may be amplified by an amplifier or converted into a digital signal by an A/D converter.

The input signal may be a signal in a time-domain. In this case, the signal in the time-domain may be converted into a signal in a frequency-domain (S**311**). Conversion of the input signal into the signal in the frequency-domain may also be performed using an FFT. The operation of converting the input signal into the signal in the frequency-domain may be omitted depending on the embodiments.

The input signal may be divided into a signal having a high frequency component and a signal having a low frequency component depending on a predetermined reference value (S**312**). Here, the predetermined reference value may be 4 kHz. However, embodiments of the present disclosure are not limited thereto. The reference value may be arbitrarily determined or changed according to the designer's or the user's selection.

Noise of the signal having the high frequency component and noise of the signal having the low frequency component may both be eliminated using the same method or may be eliminated using different methods.

When the noise of the signal having the high frequency component and the noise of the signal having the low frequency component are eliminated using different methods, the noise of the signal having the low frequency component (S**313**) may be eliminated by estimating a noise component (S**314**), estimating an SNR (S**315**), acquiring an estimated gain and a correction value (S**316**), and correcting the gain and acquiring an output signal (S**317**).

In embodiments, the noise of the signal having the low frequency component may be eliminated using a high resolution analysis algorithm. When the high resolution analysis algorithm is used to eliminate the noise of the signal having the low frequency component, the noise component may be estimated in each of frequency bands that are obtained by dividing the signal having the low frequency component (S**314**).

If the noise component is estimated, an SNR may be acquired in each of the divided frequency bands using the estimated noise component (S**315**). The SNR may be estimated using an MMSE, an RMS error, or a CMD and by further using an SPP if necessary.

If the SNR is acquired, the gain may be estimated using the SNR, and a correction value to be applied to the gain may be calculated (S**316**). Estimating the gain may be performed using an MMSE-STSA estimator, an MMSE-LSA estimator, or an OD-LSA estimator. The correction value may be determined using the relationship between the correction value and the SNR and the set value that have been described with reference to FIGS. **3** through **5**.

The relationship between the correction value and the SNR may be set in such a way that the correction value increases as the SNR increases. The relationship between the correction value and the SNR may also be set in such a way that the correction value is uniform when the SNR is in a predetermined range.

The relationship between the correction value and the SNR may be changed according to the set value. Changing the relationship between the correction value and the SNR may be performed by changing a relationship function that indicates the relationship between the correction value and the SNR or by changing at least one of an upper limit value and a lower limit value of a selectable correction value. The relationship function that indicates the relationship between the correction value and the SNR may have a shape of a linear function, an exponential function, or a log function in a particular section, as illustrated in FIGS. **3** through **5**.

If the gain and the correction value are acquired, the gain may be corrected by applying the correction value to the gain, and an output signal may be acquired by applying the corrected gain to the input signal (S**317**). The correction value may be set in such a way that, as described above, the proportion of a signal of which noise is eliminated in the output signal may be further increased when the correction value is 1 or a value that is close to 1, and the proportion of a signal which is originally input and of which noise is not eliminated in the output signal may be further increased when the correction value is a value that is close to 0.

Noise of a signal having a high frequency component (S**318**) may be eliminated by estimating a noise component (S**319**), eliminating noise (S**320**), and acquiring an output signal (S**321**). In embodiments, the noise of the signal having the high frequency component may be eliminated using a low resolution analysis algorithm.

When the low resolution analysis algorithm is used to estimate the noise of the signal having the high frequency component, a noise component may be estimated in each of frequency bands that are obtained by dividing the signal having the high frequency component (S**319**). In embodiments, an initial signal for a predetermined period or an average energy level calculated from the initial signal may be estimated as the noise.

Subsequently, the noise may be eliminated from the signal having the high frequency component using the estimated noise component (S**320**). In this case, the noise may be eliminated in each of the frequency bands. Eliminating the noise may be performed using spectral subtraction or a Wiener filter. As a result, an output signal that is a signal having the high frequency component of which noise is eliminated may be acquired (S**321**).

If the signal having the low frequency component of which noise is eliminated and the signal having the high frequency component of which noise is eliminated are acquired, the acquired signals may be synthesized with each other (S**323**). The synthesized signal may be inverted using various inversion methods including an IFFT (S**324**). A signal having a sound corresponding to the signal synthesized by an IFFT may be acquired.

The above-described method of eliminating noise may be implemented using one or two or more codes, and these codes may be programmed by a microprocessor in the apparatus for eliminating noise so as to implement the method of eliminating noise. Also, the codes for implementing the above-described method of eliminating noise may be encoded and executed by a computer. These codes may be recorded in a storage medium, such as a compact disc storage device, a semiconductor storage device, or a magnetic disk storage device.

As described above, in an apparatus and method for eliminating noise, a sound recognition apparatus using the apparatus and a vehicle equipped with the sound recognition apparatus according to embodiments of the present disclosure, a sound generated by a user speaking can be more precisely recognized with a relatively small amount of calculation even when there is much noise, and thus sound recognition performance can be improved.

In addition, in an apparatus and method for eliminating noise, a sound recognition apparatus using the apparatus and a vehicle equipped with the sound recognition apparatus according to embodiments of the present disclosure, the user's sound can be clearly recognized even when there is much noise, such as engine noise, so that components inside a vehicle can be controlled according to the user's intention and thus reliability of the sound recognition apparatus can be improved. Furthermore, user convenience can be improved, and safer driving of the vehicle can be performed.

Although embodiments of the present disclosure have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the disclosure, the scope of which is defined in the claims and their equivalents.

What is claimed is:

1. An apparatus for eliminating noise, comprising:

a gain acquisition unit that determines a gain and a correction value of the gain using a signal to noise ratio (SNR) of an input signal; and

a gain application unit that acquires an output signal corresponding to the input signal using the determined gain and the determined correction value, wherein

the output signal includes an input signal of which noise is eliminated and an input signal of which noise is not eliminated, and

a proportion of the input signal of which noise is eliminated and a proportion of the input signal of which noise is not eliminated are determined according to the determined correction value.

2. The apparatus of claim **1**, wherein the gain acquisition unit determines the correction value of the gain based on the SNR of the input signal.

3. The apparatus of claim **2**, wherein the gain acquisition unit determines the correction value of the gain based further on a set value associated with a relationship between the SNR of the input signal and the correction value, and changes the relationship between the SNR of the input signal and the correction value based on the set value, wherein the set value indicates a performance of a sound recognition apparatus.

4. The apparatus of claim **1**, wherein the correction value is determined in such a way that the correction value increases as the SNR of the input signal increases, or that the correction value has a uniform value when the SNR of the input signal is less than a first value or is greater than a second value.

5. The apparatus of claim **1**, wherein the correction value is determined in such a way that the proportion of the input signal of which noise is eliminated increases when the SNR of the input signal increases, while the proportion of the input signal of which noise is not eliminated increases when the SNR of the input signal decreases.

6. The apparatus of claim **1**, further comprising:

a noise component estimation unit that estimates noise of the input signal using at least one of a minima controlled recursive averaging (MCRA) algorithm, an improved minima controlled recursive averaging (IMCRA) algorithm, and a minimum statistics algorithm.

7. The apparatus of claim **1**, further comprising:

a SNR estimation unit that estimates the SNR of the input signal using at least one of a minimum mean square error (MMSE), a root mean square (RMS) error, a cumulative minimum distance (CMD), and a speech presence probability (SPP).

8. A sound recognition apparatus comprising:

an input unit that receives a sound signal in which an original signal and noise are mixed;

a conversion unit that converts the sound signal into a signal in a frequency-domain;

a gain acquisition unit that determines a gain and a correction value of the gain using a signal to noise ratio (SNR) of the sound signal and acquires a corrected gain obtained by applying the determined correction value to the determined gain;

a gain application unit that acquires an output signal by applying the corrected gain to the sound signal, wherein a proportion of the input signal of which noise is eliminated in the output signal and a proportion of the input signal of which noise is not eliminated in the output signal are changed according to the determined correction value; and

an inverter that inverts the output signal.

9. A vehicle comprising:

an input unit that receives a sound signal from a passenger of the vehicle in which sound instructions and noise are mixed together;

a sound recognition unit that recognizes sound instructions by: i) converting the received sound signal into a signal in a frequency-domain, ii) determining a gain and a correction value of the gain using a signal to noise ratio (SNR) of the signal in the frequency-domain, iii) acquiring an output signal by applying a corrected gain obtained by applying the determined correction value to the determined gain, and iv) inverting the output signal, wherein a proportion of the received sound signal of which noise is eliminated in the output signal and a proportion of the received sound signal of which noise is not eliminated in the output signal are changed based on the determined correction value; and

a controller that generates a control signal based on the recognized sound instructions.

10. A method of eliminating noise, comprising:

determining a gain and a correction value of the gain using a signal to noise ratio (SNR) of an input signal;

acquiring a corrected gain obtained by applying the determined correction value to the determined gain; and

acquiring an output signal by applying the corrected gain to the input signal, wherein a proportion of an input signal of which noise is eliminated in the output signal and a proportion of the input signal of which noise is not eliminated in the output signal are changed based on the determined correction value.

11. The method of claim **10**, wherein the determining of the correction value of the gain comprises:

determining the correction value of the gain based on a relationship between the SNR of the input signal and the correction value.

12. The method of claim **10**, wherein the determining of the correction value of the gain comprises:

determining the correction value of the gain based further on a set value associated with a relationship between the SNR of the input signal and the correction value.

13. The method of claim **10**, wherein the correction value is determined in such a way that the correction value increases as the SNR of the input signal increases, or the correction value has a uniform value when the SNR of the input signal is less than a first value or is greater than a second value.

14. The method of claim **10**, wherein the correction value is determined in such a way that the proportion of the input signal of which noise is eliminated increases when the SNR of the input signal increases, while the proportion of the input signal of which noise is not eliminated increases when the SNR of the input signal decreases.

15. The method of claim **10**, further comprising:

estimating noise of the input signal using at least one of a minima controlled recursive averaging (MCRA) algorithm, an improved minima controlled recursive averaging (IMCRA) algorithm, and a minimum statistics algorithm.

16. The method of claim **10**, further comprising:

estimating the SNR of the input signal using at least one of a minimum mean square error (MMSE), a root mean square (RMS) error, a cumulative minimum distance (CMD), and a speech presence probability (SPP).

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